VOL. XIV APRIL 1960 NO. 2

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

CHARLES E. CUTRESS and WILLIS E. PEQUEGNAT
Three New Zoantharia from California

B. M. BARY
Pelagic Tunicates from New Zealand

KEITH H. WOODWICK
Early Larval Development of Polydora nuchalis

ALBERT H. BANNER and DORA MAY BANNER
Alpheid Shrimp of the Pacific Ocean, Part V

IRWIN M. NEWELL
Charadracarus, A New Genus of Mites

WALTER M. MATSUMOTO
Hawaiian Frigate Mackerel of the Genus Auxis

R. W. TAYLOR
Taxonomic Notes on Ponera leae and P. norfolkensis

UNIVERSITY OF HAWAII PRESS

BOARD OF EDITORS

O. A. BUSHNELL, *Editor-in-Chief*
Department of Bacteriology, University of Hawaii

MARION P. GODDARD, *Assistant to the Editors*
Office of Publications and Information, University of Hawaii

AGATIN T. ABBOTT
Department of Geology and Geophysics
University of Hawaii

THOMAS S. AUSTIN
Bureau of Commercial Fisheries, Hawaii Area
(U. S. Fish and Wildlife Service)
Honolulu, Hawaii

BRIAN M. BARY
Institute of Oceanography
University of British Columbia
Vancouver, Canada

ALBERT J. BERNATOWICZ
Department of Botany
University of Hawaii

HOWARD BOROUGHS
Instituto Interamericano de Ciencias Agricolas
Turrialba, Costa Rica

E. H. BRYAN, JR.
Bernice P. Bishop Museum
Honolulu, Hawaii

KOJI HIDAKA
Geophysical Institute
Tokyo University
Tokyo, Japan

COLIN S. RAMAGE
Department of Geology and Geophysics
University of Hawaii

PAUL J. SCHEUER
Department of Chemistry
University of Hawaii

ALBERT L. TESTER
Department of Zoology and Entomology
University of Hawaii

MIKLOS F. UDVARDY
Department of Zoology and Entomology
University of Hawaii

THOMAS NICKERSON, *Managing Editor*
Office of Publications and Information, University of Hawaii

SUGGESTIONS TO AUTHORS

Contributions to Pacific biological and physical science will be welcomed from authors in all parts of the world. (The fields of anthropology, agriculture, engineering, and medicine are not included.) Manuscripts may be addressed to the Editor-in-Chief, PACIFIC SCIENCE, University of Hawaii, Honolulu 14, Hawaii, or to individual members of the Board of Editors. Use of air mail is recommended for all communications.

Manuscripts will be acknowledged when received and will be read promptly by members of the Board of Editors or other competent critics. Authors will be notified as soon as possible of the decision reached.

Manuscripts of any length may be submitted, but it is suggested that authors inquire concerning possibilities of publication of papers of over 30 printed pages before sending their manuscripts. Authors should not overlook the need for good brief papers, presenting results of studies, notes and queries, communications to the editor, or other commentary.

PREPARATION OF MANUSCRIPT

It is requested that authors follow the style of *Pacific Science* described herein and exemplified in the journal.

Manuscript Form. Manuscripts should be typed on one side of standard-size, white bond paper and double-spaced throughout. Pages should be consecutively numbered in upper right-hand corner. Sheets

(Continued on inside back cover)

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

VOL. XIV APRIL 1960 NO. 2

Previous issue published January 12, 1960

CONTENTS

PAGE

Three New Species of Zoantharia from California. *Charles E. Cutress and Willis E. Pequegnat* 89

Notes on Ecology, Distribution, and Systematics of Pelagic Tunicata from New Zealand. *B. M. Bary* 101

Early Larval Development of Polydora nuchalis *Woodwick, a Spionid Polychaete.* *Keith H. Woodwick* 122

Contributions to the Knowledge of the Alpheid Shrimp of the Pacific Ocean, Part V. The Indo-Pacific Members of the Genus Athanas. *Albert H. Banner and Dora May Banner* 129

Charadracarus *new genus, Charadracarinae new subfamily (Acari, Johnstonianidae), and the Status of* Typhlothrombium *Berlese 1910.* *Irwin M. Newell* 156

Notes on the Hawaiian Frigate Mackerel of the Genus Auxis. *Walter M. Matsumoto* 173

Taxonomic Notes on the Ants Ponera leae *Forel and* Ponera norfolkensis *(Wheeler) (Hymenoptera–Formicidae).* *R. W. Taylor* 178

NOTES:

Fatal Shark Attack, Oahu, Hawaii, December 13, 1958. *Albert L. Tester* 181

Introduction of the Marquesan Sardine, Harengula vittata *(Cuvier and Valenciennes), to Hawaiian Waters.* *Garth I. Murphy* 185

PACIFIC SCIENCE is published quarterly by the University of Hawaii Press, in January, April, July, and October. Subscription price is $4.00 a year; single copy, $1.25. Check or money order payable to University of Hawaii should be sent to University of Hawaii Press, Honolulu 14, Hawaii, U. S. A. Printed by Star-Bulletin Printing Company, Inc., 420 Ward Avenue, Honolulu 14, Hawaii.

Three New Species of Zoantharia from California

CHARLES E. CUTRESS and WILLIS E. PEQUEGNAT[1]

PREVIOUS TO THE DISCOVERY of the species to be described in this paper, 20 species of Zoantharia belonging to 4 genera were known from the eastern Pacific Ocean. Nine of the species were described from the Gulf of California by Carlgren (1951). With the additional species described by Verrill (1866, 1869) from Central America and one described from Panama by Le Conte (1851), there are 15 species of Zoantharia known from the warm waters of the Gulf of Panama and Gulf of California. Four species have been described from the coasts of Chile and Juan Fernandez, one by McMurrich (1904) and three by Carlgren (1898, 1920). Between this region and Panama virtually nothing is known of the zoantharian fauna. North of the Gulf of California to the southern coast of Alaska there is known but a single zoanthid, the species being described by Wood (1958).

THE ZOANTHARIA OF THE EASTERN PACIFIC OCEAN

Epizoanthus californicum Carlgren, 1951, p. 436, text fig. 82, a–d, pl. 14, fig. 7. La Paz, Baja California.

——— *crassum* Verrill, 1869, p. 498. San Salvador.

——— *elongatum* Verrill, 1869, p. 497. Peru and Pearl Islands.

——— *gabrieli* Carlgren, 1951, p. 438, pl. 14, fig. 6. Espiritu Island, Gabriel Bay, Baja California.

——— *humile* Verrill, 1869, p. 498. Panama.

——— *patagonichum* Carlgren, 1898, p. 38, fig. 1. S. 40° 14′ W. 61° 23′. McMurrich, 1904, p. 296, pl. 19, figs. 85, 86. Calbuco, Chile. Carlgren, 1927, p. 94, text fig. 62. South of Falkland Islands.

——— *scotinus* Wood, 1958, p. 707. Puget Sound, Washington.

Palythoa complanata Carlgren, 1951, p. 438, text figs. 82, e, f, pl. 14, fig. 9. Puerto Escondido, Baja California.

——— *ignota* Carlgren, 1951, p. 440, text figs. 83, c, d, pl. 14, fig. 12. Angeles Bay, Baja California.

——— *insignis* Carlgren, 1951, p. 441, text figs. 84, a–c, pl. 14, fig. 13. Coronado Island, Baja California.

——— *pazi* Carlgren, 1951, p. 442, text fig. 84, d, pl. 14, fig. 14. La Paz, Baja California.

——— *praelonga* Carlgren, 1951, p. 439, text figs. 82, g, h, pl. 14, fig. 10. Gabriel Bay, Baja California.

——— *rickettsi* Carlgren, 1951, p. 440, text figs. 83, a, b, pl. 14, fig. 11. Tiburón Island, Baja California.

Parazoanthus elongatum McMurrich, 1904, p. 298, pl. 19, figs. 87–89. Calbuco, Chile.

——— *fuegiensis* Carlgren, 1898, p. 39, fig. 6. Dawson Island, Strait of Magellan.

——— *juanfernandez* Carlgren, 1920, p. 148, text fig. 3, pl. 6, fig. 3. Juan Fernandez.

Zoanthus confertum (Verrill). *Mammillifera conferta* Verrill, 1869, p. 497. San Salvador.

——— *danae* Le Conte. *Zoantha danae* Le Conte, 1851, p. 320. Panama. *Mammillifera danae*, Verrill, 1869, p. 496. Pearl Islands. *Zoanthus danae*, Verrill, 1866, p. 329. Panama. Carlgren, 1951, p. 443, text figs. 84, e–h. Escondido, Coronado, Concepcion Bay, Baja California.

——— *depressum* Carlgren, 1951, p. 444, text fig. 84, i. Cape San Lucas, Baja California.

——— *nitidum* (Verrill). *Mammillifera nitida* Verrill, 1869, p. 497. San Salvador.

The three species of *Parazoanthus* known until now from the eastern Pacific are all from the southern end of South America. The new fourth species, *P. lucificum*, in addition to being the first reported from the northeast Pacific Ocean, also is the first reported instance of a member of the genus occurring regularly on a

[1] Smithsonian Institution and Department of Zoology, Pomona College, Claremont, California. Manuscript received January 29, 1959.

gorgonian and along with *Epizoanthus induratum* furnishes the first cases of bioluminescence in the order. The new species *Epizoanthus leptoderma* and *E. induratum* are the seventh and eighth of the genus to be reported from the eastern Pacific and the fourth and fifth from the area of Lower California and California.

The specimens of *Parazoanthus lucificum*, *Epizoanthus leptoderma*, and *E. induratum* herein described are from material collected in conjunction with an ecological survey, being conducted by the junior author, of several shallow water shale reefs off the coast of Corona del Mar, California.

The finding of three new zoantharians in subtidal water in the same area attests to the scantiness of our knowledge of the subtidal fauna of the comparatively intensely studied coast of California. More specifically, the collection of these new zoanthids by SCUBA diving at depths of 25 to 100 feet points to a possible existence at these depths of a fauna, at least in part, unlike that of either the littoral or deep water.

Family PARAZOANTHIDAE

Parazoanthus Haddon and Shackleton, 1891

Parazoanthus Haddon and Shackleton, 1891, p. 653. Type species by original designation: *Palythoa axinellae* Schmidt, 1862, pp. 61, 62, pl. 6, figs. 2, 3. Gender: neuter.

Parazoanthidae with a diffuse marginal sphincter muscle in the entoderm. Scapus and coenenchyme incrusted with foreign material. Ectoderm continuous. Mesogloea with an encircling sinus as well as ectodermal canals, lacunae, and cell islets. Polyps usually colonial and connected by bandlike or incrusting coenenchyme. Dioecious.

The diagnosis of the genus as it is given here is essentially that of Haddon and Shackleton.

Parazoanthus lucificum n. sp.

Figs. 1–3

TYPE MATERIAL: Holotype, U.S. Nat. Mus. Cat. No. 50975, one colony of 200 to 300 polyps. From off Corona del Mar, California, at a depth of 75 feet. Collected by Willis E. Pequegnat, May 5, 1957. Colony incrusting a dead gorgonian which was attached to a shale reef.

Paratype, U.S. Nat. Mus. Cat. No. 50976, one colony of 300 to 400 polyps. From 1 mile south of Corona del Mar, California, at a depth of 85 feet. Collected by Willis E. Pequegnat, April 25, 1958. Colony incrusting a dead gorgonian which was attached to a shale reef.

DIAGNOSIS: Colony large, consisting of numerous moderately crowded polyps. Coenenchyme thin and incrusting. Scapus thin-walled. Surface of the ectoderm sparsely incrusted with fine sand and shell. Ridges of the scapulus to 17 in number, indistinct in contracted polyps but distinct in expanded ones. Tentacles and mesenteries to 30 in number. Marginal sphincter muscle in the entoderm weak. Mesogloea with an extensive encircling sinus and few cell islets. Holotrichs absent. The species grows upon the gorgonian *Muricea californica*, is brilliantly bioluminescent and secretes copious quantities of

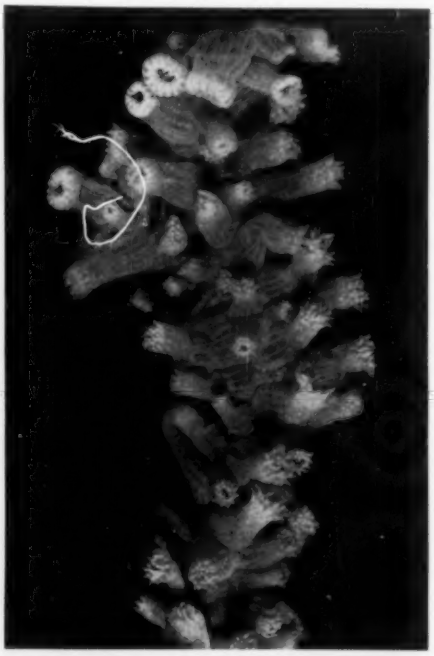


FIG. 1. *Parazoanthus lucificum*. A portion of the paratype. × 1.5.

thick sticky slime upon stimulation or when removed from the water.

DESCRIPTION: *Size.* In life the largest polyps are 15 mm. long and 3.5 mm. in diameter. In the preserved semiexpanded condition the largest polyps of the holotype are about 4 mm. long and 2.5 mm. in diameter. The holotype colony almost completely covers the numerous branches of a 20 cm. gorgonian.

External Aspects. P. lucificum occurs at depths of 40 to 90 feet and is found on about 5 per cent of the *Muricea californica* in the Corona del Mar area. Whole colony brilliantly bioluminescent and secreting copious quantities of slime. Coenenchyme thin and incrusting, for the most part completely investing the branches of the gorgonian. Polyps numerous, moderately crowded, not arranged in a definite pattern. Scapus thin-walled, allowing the insertions of the mesenteries to show through. Ridges of the scapulus numbering to 17, indistinct in contracted polyps but distinct in expanded ones. On some of the well-expanded polyps the ridges of the scapulus resemble incrusted marginal vesicles. Between each ridge (just below each outer tentacle) there is a distinct V-shaped area devoid of incrustation. Coenenchyme and scapus surface sparsely incrusted with very fine sand, shell, occasional sponge spicules and foraminifers. Tentacles arranged in two cycles, moderately long, to 30 in number. Color of living specimens is bright yellow with a distinct orange ring around the mouth which extends into the actinopharynx and along the macrocnemes near the gonads.

Sphincter. In the entoderm, weak, made up of 15 to 18 low simple plaits, diffuse (Fig. 2).

Mesenteries. To 30 in number. In the 15 polyps examined the following numbers of mesenteries were observed: (25) 8, (27) 3, (28) 3, (30) 1. The polyp with 30 mesenteries had 17 macrocnemes and 13 microcnemes. The filaments are attached throughout their length to the macrocnemes and extend about three-fourths of the distance from the actinopharynx to the base. The scanty gonads are borne on the macrocnemes just below the actinopharynx. Retractor muscles of the macrocnemes very weak, diffuse (Fig. 3). Microcnemes scarcely extending above the column entoderm. The polyps of the holotype are female and those of the paratype, male. The gonads are ripe during June, July, and August. The larvae are retained within the body until they are well developed and are commonly observable in the lumens of the tentacles. The larva is of the zoanthella type.

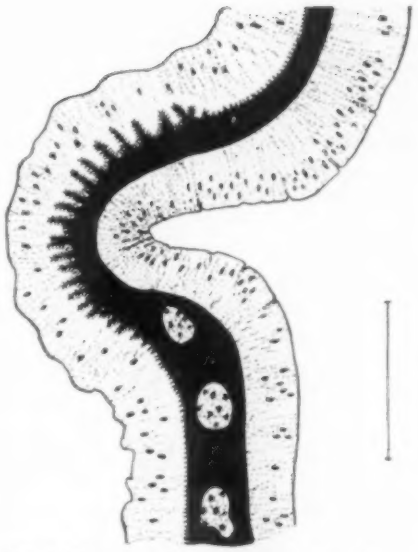


FIG. 2. Transverse section of the marginal sphincter muscle of *Parazoanthus lucificum*. Scale = .10 mm.

Actinopharynx. Longitudinally corrugated. Siphonoglyph shallow but distinct. Hyposulcus indistinct, only slightly shorter than the siphonoglyph. Ectoderm without mucous or eosinophilic gland cells.

Mesogloea. With an extensive encircling sinus which is lined with cells similar to those of the ectoderm, with lacunae which do not contain cells, and with few cell islets. Containing very little of the incrusting material.

Ectoderm. Continuous, about one half the thickness of the mesogloea and containing most of the sparse incrusting material. With no mucous cells but on the surface and in some parts of the encircling sinus with a diffusely distributed nonparticulate material (probably the slime) which stains like mucus with hematoxylin.

Entoderm. Without zooxanthellae.

Cnidom. Spirocysts, of the tentacles, 18 to 22 by 3 μ, very numerous. Microbasic b-mastigo-

phores, of the tentacles, 18 to 22 by 3 to 4 μ, few (mostly at the tips); of the actinopharynx, 18 to 20 by 3 to 3.5 μ, few. Microbasic p-mastigophores, of the actinopharynx, 14 to 18 by 5 μ, few; of the filaments, 13 to 22 by 4.5 to 6 μ, common. No nematocysts could be found in either the ectoderm or the entoderm of the column. Holotrichs are absent.

DISCUSSION

Especially noteworthy among the several distinguishing features of *Parazoanthus lucificum* is its brilliant bioluminescence. E. N. Harvey (1952; 1955) gives no references to luminous Anthozoa excepting the Alcyonaria and none could be found in a rather thorough review of the literature on the Zoantharia. From this we in no way conclude that *P. lucificum* is unique in this respect, but we do believe that this is the first reported instance of bioluminescence for the genus *Parazoanthus*. Because of its bioluminescence we have given to the species the Latin name *lucificum*, denoting "light producer."

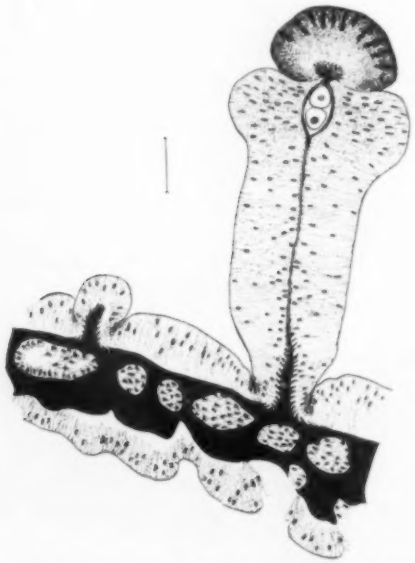


FIG. 3. Transverse section of a macro- and microcneme of *Parazoanthus lucificum*. Only the encircling sinus is shown in the column mesogloea. Section taken from mid-column. Scale = .10 mm.

The bioluminescence is restricted to the tentacles which flash both in the expanded and contracted state. The phenomenon is observed upon appropriate stimulation only. A sufficiently strong stimulus causes a large number of the polyps to light up. The glow is not steady at first but is characterized by intermittent flashes at the end of which time it continues steadily for as much as 10 seconds and then dims out. Because of the recurrent flashing, suggestive of nondirectional neural control, and negative smears for bacteria, it is our conclusion that the luminosity is intrinsic to the zoanthid. However, cells or granules that might be associated with the phenomenon were not observed.

P. lucificum grows upon the gorgonian *Muricea californica*. After the zoanthella larva settles on a living *M. californica* the zoanthid rapidly and entirely replaces the soft parts of the gorgonian. It appears that once the zoanthid is established the gorgonian has little or no defense against further encroachment. At the approach of the zoanthid's coenenchyme the gorgonian's tissues soften and slough off leaving exposed an area of bare skeleton which soon becomes occupied by a zoanthid polyp. This process continues until the gorgonian is completely removed from its skeleton. Although two other genera of gorgonians are found off Corona del Mar, *P. lucificum* does not grow on them. *P. lucificum* has been found growing only on *Muricea californica* in spite of the fact that a second species, *M. fruticosa*, may in places grow side by side with the former. *P. lucificum* is the only known species of the genus to be regularly associated with a gorgonian.

Morphologically and anatomically *P. lucificum* is most similar to *P. dichroicum* Haddon and Shackleton, 1891, *P. gracile* (Lwowsky, 1913), and *P. tunicans* Duerden, 1900. It can, however, be distinguished from *P. dichroicum* by its yellow color, lack of dichroism, fewer mesenteries, and larger polyps. Compared to *P. gracile*, *P. lucificum* has fewer mesenteries, larger polyps, and in the mesogloea lacks the peculiar cells with crystal-like inclusions (Lwowsky, 1913; Carlgren, 1934). The difference in the number of macrocnemes between *P. lucificum* and *P. tunicans* (to 17 in the former; to 16 in the latter) is too slight to be of diagnostic value. While

there is a difference in the zoogeographical distribution, host, and polyp size between the two species, probably the most important diagnostic character is the absence of holotrichous nematocysts in *P. lucificum* while they are relatively abundant in *P. tunicans*.

In summary, the distinguishing features of *P. lucificum* are its brilliant bioluminescence, sliminess, affinity for the gorgonian *Muricea californica*, lack of holotrichs, and, in most cases, its complement of mesenteries.

Family EPIZOANTHIDAE
Epizoanthus Gray, 1867

Epizoanthus Gray, 1867, p. 237. Type species by monotypy: *Duseidela? papillosa* Johnston, 1842, pp. 190, 251 (in part), text fig. 18 (not pl. 16, figs. 6, 7), = *Epizoanthus incrustatus* (Düben and Koren, 1847), p. 268. Gender: neuter.

DIAGNOSIS: Epizoanthidae with a single marginal sphincter muscle in the mesogloea. Scapus and coenenchyme incrusted with foreign material. Ectoderm usually continuous but may occasionally be discontinuous. Mesogloea often with cell islets and lacunae. Polyps either colonial or solitary. Coenenchyme bandlike, incrusting or greatly reduced in solitary forms. Dioecious.

Epizoanthus leptoderma n. sp.
Figs. 4–6

TYPE MATERIAL: Holotype, U.S. Nat. Mus. Cat. No. 50974, two portions of one colony with a total of 80 to 90 polyps. From a shale reef, depth 40 feet, Corona del Mar, California. Collected by Robert Given, August 25, 1957.

DIAGNOSIS: Colony large, consisting of numerous, moderately crowded, elongate polyps arising from a moderately thick, incrusting coenenchyme. Scapus thin-walled. Ectoderm of the scapus and coenenchyme moderately incrusted with sand. Ridges of the scapulus indistinct, to 18 in number, agreeing with the macrocnemes. Marginal sphincter muscle in the mesogloea, moderately strong, broad and transversely stratified. Tentacles and mesenteries to 36 in number. Mesogloea with few lacunae and cell islets but with single elliptical cells especially in the regions of the oral disc and actinopharynx.

DESCRIPTION: *Size.* In the preserved semicontracted state the polyps vary in length and diameter from 5 by 1.5 mm. to 20 by 5 mm. The largest portion of the colony is about 4 cm. in diameter at the base.

External Aspects. Polyps elongate, moderately crowded and arising from a moderately thick, incrusting coenenchyme. Scapus thin-walled, allowing the mesenterial insertions to show through. Surface of the scapus and coenenchyme with a moderately dense incrustation of fine black and white sand. Ridges of the scapulus to 18 in number, indistinct in contracted specimens. Tentacles of medium length, thin, numbering to 36 in large polyps. Color in life tan, with narrow, transverse, brown bands on the tentacles. Color in alcohol, scapus and coenenchyme gray, tentacles gray with one to several narrow, transverse, violet bands. The species occurs on shale reefs at depths of 15 to 45 feet. It is common on protected ledges.

Marginal Sphincter Muscle. In the mesogloea, moderately strong, broad and transversely stratified (Fig. 5).

Mesenteries. Usually agreeing in number with the tentacles. Those of the 10 largest specimens were (36) 1, (34) 1, (33) 4, (32) 2, and (30) 2. Several of the smallest specimens had 30 mesenteries. Polyps with 36 mesenteries have 18 macro- and microcnemes. Mesogloea lamina of the mesenteries thin. Retractor muscles of the macrocnemes very weak and diffuse (Fig. 6). The microcnemes scarcely extend above the column entoderm. Gonads were not apparent in the specimens examined.

Actinopharynx. Ectoderm with few gland cells and with olive-colored pigment granules in the basal portion. Siphonoglyph distinct, slightly longer than the indistinct hyposulcus.

Mesogloea. With a few small lacunae and a few cell islets but with rather numerous, single, elliptical cells especially in the regions of the oral disc and actinopharynx. The elliptical cells of the column are more numerous next to the entoderm. Mesogloea of the column about four or five times the thickness of the ectoderm, containing a little sand and an occasional sponge spicule.

FIG. 4. *Epizoanthus leptoderma*. The largest portion of the holotype. × 1.5.

Ectoderm. That of the scapus and coenenchyme containing most of the sand. That of the tentacles and oral disc with olive-colored granules at the locations of the violet markings. With little or no pigmentation in the column.

Entoderm. Without zooxanthellae.

Cnidom. Spirocysts, of the tentacles, 12 to 15 by 2.5 to 3 μ, very numerous. Basitrichs, of the tentacles, 12 by 2 to 2.5 μ, few. Microbasic b-mastigophores, of the tentacles, 12 to 15 by 3 to 3.5 μ, few; of the actinopharynx, 12 to 18 by 2 to 2.5 μ, common. Microbasic p-mastigophores, of the actinopharynx, 12 by 4.5 μ, few; of the filaments, 12 to 20 by 4.5 μ, numerous. Holotrichs, of the actinopharynx (entoderm), 37 to 40 by 12 to 15 μ, common; of the filaments, 37 to 40 by 12 to 15 μ, common. No nematocysts could be found in the column.

DISCUSSION

Superficially *E. leptoderma* appears to be intermediate between *E. gabrieli* Carlgren and *E. californicum* Carlgren. The growth form and dimensions of the *E. leptoderma* colony and polyps are essentially the same as those of *E. californicum*. The chief external difference between these two species is the thinner column wall and weaker incrustation of *E. leptoderma* (the characteristic for which this species is named). Histological examination, in addition, reveals that the marginal sphincter of *E. leptoderma* is much weaker and shorter than that of *E. californicum*. Although there is an overlap in the number of mesenteries between the two species, it is only an occasional polyp of *E. leptoderma* that will have the lesser mesenterial complement of *E. californicum*. The mesogloea, especially of the column, of the latter species is several times as thick as that of *E. leptoderma* and, furthermore, the cells of the mesogloea of *E. californicum* are larger, more numerous, and have a different distribution. The cells of the mesogloea of the column of *E. leptoderma* are concentrated near the entoderm, whereas in *E. californicum* these cells are uniformly distributed. There is close agreement in the dimen-

FIG. 5. Transverse section of the marginal sphincter muscle of *Epizoanthus leptoderma*. Scale = .10 mm.

sions of the nematocysts of the two species but the distribution of the kinds is slightly different.

Comparing *E. leptoderma* with *E. gabrieli*, we find that the colony and polyps of the former species are larger and the scapus and coenenchyme are thinner and more sparsely incrusted. Internally the marginal sphincter muscle of *E. leptoderma*, although slightly weaker, resembles that of *E. gabrieli*, but only in its upper part. Whereas the sphincter of *E. leptoderma* is short, that of *E. gabrieli* tapers gradually to a long tail which becomes alveolar (Fig. 7).

One point of similarity that at first seemed important was the tendency of the cells of the mesogloea to be concentrated near the entoderm. Carlgren, 1951, stresses this feature as a characteristic of *E. gabrieli*. However, in the sections of a second polyp of *E. gabrieli* we found that these same cells are rather evenly distributed in the mesogloea. In the case of *E. leptoderma*, the concentration of cells of the mesogloea near the entoderm was rather obvious in all the polyps sectioned.

When the mesenteries of the two species are compared in sections taken from a point half way between the end of the actinopharynx and the pedal disc, it is found that the microcnemes are about one half the length of the macrocnemes in *E. gabrieli* while in *E. leptoderma* the free edges of the microcnemes scarcely extend beyond the margin of the column entoderm. In the former species, near the column, the mesogloeal lamellae of both micro- and macrocnemes are greatly thickened, a feature which Carlgren, 1951, does not mention. In contrast, the mesogloeal lamellae of the mesenteries in *E. leptoderma* are weak and there is little difference in their thickness from column to free edge (compare Figs. 6 and 8). The difference in appearance of this musculature in the two species is not due to differential contraction, for sections of both contracted and expanded polyps of *E. leptoderma* were compared with those of *E. gabrieli*. As the polyps of both species had inactive gonads, the different appearance of the mesenteries could not be due to differences in this physiological state. We think the differences between the mesenteries of *E. leptoderma* and *E. gabrieli* are morphological and constant.

FIG. 6. Transverse section of a macro- and microcneme of *Epizoanthus leptoderma*. Shown in the column wall mesogloea are cells concentrated near the entoderm. Section taken from mid-column. Scale = .10 mm.

It seems clear to us that, although *E. leptoderma* possesses a few characters of both *E. gabrieli* and *E. californicum*, for the most part these similarities are outweighed by the unique characters of each species, and in our estimation the three are distinct species.

Epizoanthus induratum n. sp.
Figs. 7–9

TYPE MATERIAL: Holotype, U.S. Nat. Mus. Cat. No. 51054, one colony of about 60 polyps. From Corona del Mar, California, 1 mile S. E. of Newport Harbor entrance and one half mile

off shore at a depth of 75 feet. Collected by Willis E. Pequegnat, November 6, 1958. Colony incrusting the base and lower portions of a *Muricea californica* which was attached to a shale reef.

Paratype, U.S. Nat. Mus. Cat. No. 51055, one colony of about 20 polyps. From Corona del Mar, California, one half mile off shore at a depth of 75 feet. Collected by Willis E. Pequegnat, November 6, 1958. Colony incrusting a piece of shale.

Paratype, U.S. Nat. Mus. Cat. No. 51058, several fragments of a colony with a total of about 100 polyps. From 1⅓ miles S. E. of Corona del Mar, California, at a depth of 75 feet. Collected by Willis E. Pequegnat, November 26, 1958. Colony incrusting a piece of shale.

DIAGNOSIS: Colonies large, consisting of numerous, rather widely separated polyps. Coenenchyme moderately thick, incrusting, greatly expanded and heavily impregnated with fine sand. Scapus thick-walled, heavily impregnated with fine sand. Ridges of the scapulus to 22 in number, indistinct in contracted polyps but prominent in expanded ones. Tentacles and mesenteries to 38 in number. Marginal sphincter muscle in the mesogloea moderately strong. Mesogloea thick, with few single cells except in the actinopharynx, few lacunae, and few or no cell islets. The species grows principally upon shale but may occasionally be found on the gorgonian *Muricea californica*, is bioluminescent and pale salmon in color.

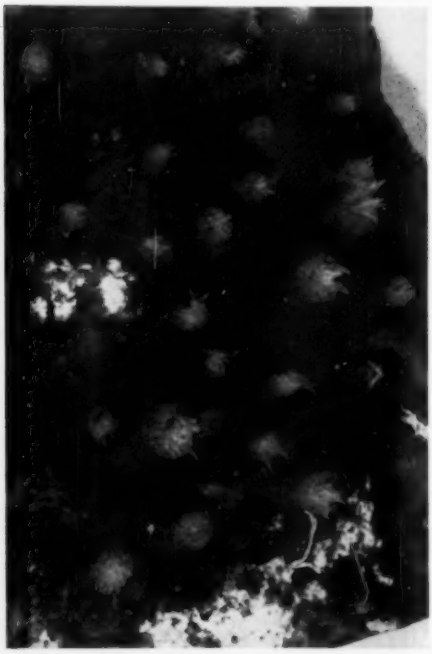


FIG. 7. *Epizoanthus induratum*. Paratype. × 1.5.

DESCRIPTION: *Size*. Of large expanded living polyps, length 7 mm., diameter of oral disc 6 mm., length of tentacles 7 mm. In a preserved, semicontracted state the polyps vary in length and diameter from 1 by 1.5 mm. to 5 by 4 mm. The holotype colony covers the base (about 5 by 8 cm.) of a *Muricea californica* and extends along several of the main branches of the gorgonian for a distance of about 8 cm.

External Aspects. Epizoanthus induratum occurs on shale and the gorgonian *Muricea californica* at 75 feet or more. It is an abundant species in the Corona del Mar area and has been observed to form colonies 10 square meters or more on the shale bottom. The species is firm, rough to the touch and bioluminescent. Coenenchyme incrusting, moderately thick, very much expanded, and heavily incrusted with fine silicious sand. Polyps numerous, those of colonies growing upon shale rather widely separated one from the other but those of colonies growing upon gorgonians closer together. Polyps randomly arranged and unequal in size (small ones interspersed with large ones). Some of the polyps of the preserved specimens are high and free while others, presumably more contracted, scarcely extend above the surrounding coenenchyme (Fig. 7). Scapus thick-walled, heavily incrusted with fine silicious sand. Ridges of the scapulus prominent in expanded polyps but indistinct in contracted ones, to 22 in number. Scapulus devoid of incrustation except for the ridges which are heavily incrusted. Tentacles long, to 38 in number. Color in life pale salmon, tentacles unmarked, mouth edged with white and immediately peripheral to this a ring of yellow.

Sphincter. Moderately strong, lying in the outer portion of the mesogloea, broadest in its

upper part and abruptly tapered below, for the greater part openly stratified and with large interstices and thick trabeculae (Fig. 8). Some of the interstices containing large cells with eosinophilic granules.

Mesenteries. To 38 in number. In six of the largest polyps examined the following numbers of mesenteries were observed: 22 + 16 = 38 (1), 20 + 14 = 34 (1), 19 + 13 = 32 (1), and 18 + 12 = 30 (3). Retractor muscles of the macrocnemes very weak, diffuse. Below the actinopharynx the macrocnemes are borne on high, longitudinal ridges projecting from the body wall into the coelenteron (Fig. 9). These ridges are thickenings in the column wall involving both the mesogloea and entoderm. All polyps sectioned were male and bore ripe testes.

Actinopharynx. Smooth. Ectoderm with numerous acidophilic and few mucous gland cells. Siphonoglyph prominent, considerably longer than the actinopharynx. Hyposulcus indistinct, same length as actinopharynx.

Mesogloea. Of the scapus, 30 to 40 times the thickness of the entoderm, with a few scattered cells, few lacunae, and few or no cell islets; densely packed with sand throughout even into the ridges of the lower column upon which the macrocnemes are borne. Of the actinopharynx (siphonoglyph excepted), with rather numerous, large cells having a vacuolated cytoplasm. Of the oral disc, without cells.

Ectoderm. Of the column, continuous, about one tenth the thickness of the mesogloea; containing sand, few mucous cells and numerous acidophilic gland cells. Of the oral disc, with few or no nematocysts but with numerous acidophilic gland cells especially around the mouth where the epithelium is unusually high. Among the acidophilic gland cells are cells (20 by 6 to 7 μ) containing nonstaining granules (.75 to 1.5 μ).

Entoderm. Without zooxanthellae. Of the column, with numerous acidophilic gland cells. Of the actinopharynx and adjacent portions of macrocnemes, with large cells, similar to those of the ectoderm, containing large nonstaining granules.

Cnidom. Spirocysts, of the tentacles, 10 to 12 by 2 μ, pyriform, very numerous. Microbasic b-mastigophores, of the tentacles, 15 by 2.5 to 3 μ, few; of the actinopharynx, 18 to 22 by 3 μ, numerous. Microbasic p-mastigophores, of the filaments, 15 to 19 by 5 μ, numerous. Holotrichs, of the tentacles, 25 to 30 by 8 to 10 μ, numerous; of the column (ectoderm), 20 to 28 by 8 to 10 μ, common; of the actinopharynx, 30 by 10 μ, few; of the filaments, 30 to 37 by 10 to 11 μ, numerous.

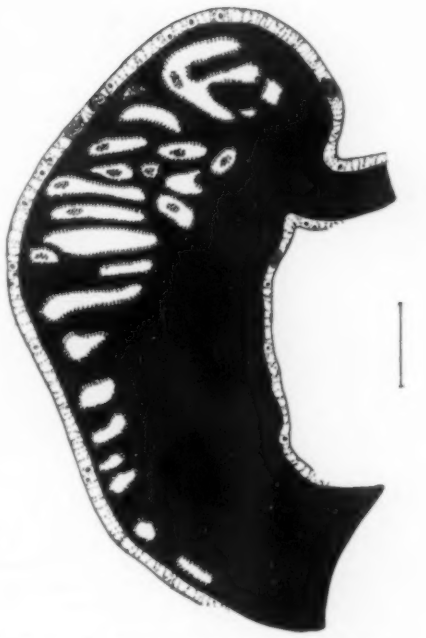


FIG. 8. Transverse section of the marginal sphincter muscle of *Epizoanthus induratum*. Scale = .10 mm.

DISCUSSION

Epizoanthus induratum is a common species in the Corona del Mar area at depths of 75 feet and more. It has been observed to grow upon shale and the gorgonian *Muricea californica* but is more frequently found on the former substrate. Those colonies on *Muricea* become established on the living gorgonian and encroach upon it in the same manner as has been described for *Parazoanthus lucificum*. In reference to the firmness of this new *Epizoanthus*, caused by the dense incrustation of sand, the Latin ad-

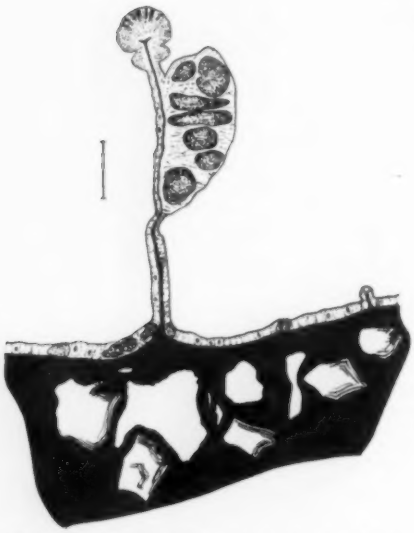


FIG. 9. Transverse section of a macro- and micrcneme of *Epizoanthus induratum*. The dense incrustation of the ectoderm and mesogloea has been largely omitted. Section taken from mid-column. Scale = .10 mm.

jective *induratum* (hardened) has been selected for the name of the species.

With respect to bioluminescence, *E. induratum* is not so bright as *Parazoanthus lucificum*. Whereas the source of luminescence in the latter species could not be determined, in the case of *E. induratum* it is very likely associated with the cells with large nonstaining granules that occur in the ectoderm around the mouth and in the entoderm of the actinopharynx and adjacent portions of the macrocnemes. There is no direct evidence that these cells are luminous; nevertheless, their distribution in the polyp and the resemblance they bear to the luminous cells of *Pelagia* (Harvey, 1952, fig. 47) strongly suggest they have to do with the light production observed in the living zoanthid.

Superficially the growth form of *E. induratum* which occurs on *Muricea* very closely resembles *Parazoanthus lucificum*. However, unlike *P. lucificum*, *E. induratum* is not slimy and only infrequently grows upon gorgonians. Among the species of *Epizoanthus*, *E. induratum* resembles only *E. papillosum* of the North Atlantic Ocean and then only in certain anatomical features. For example, the number of mesenteries is the same in both species; the sphincter muscle in *E. induratum*, although slightly weaker, is very much like that of *E. papillosum*, and in contraction the sphincter imparts a truncate appearance to the distal ends of the polyps of both species. Other features the two species have in common are few cells and lacunae in the mesogloea, heavy incrustation of sand, and prominent ridges on the scapulus. The two species differ chiefly in growth form and geographical distribution. Although it is conceivable that the same species might occur in both the North Atlantic and North Pacific oceans, the predominant habit of *E. papillosum* to form carcenoecia or occasionally small, unattached colonies strongly suggest we have to do with two species. In addition, the nonagreement in size and distribution of nematocysts, the inconspicuous microcnemes, its bioluminescence, and the peculiar aggregation of acidophilic gland cells around the mouth of *E. induratum* leaves little doubt that the species is new.

Undoubtedly occasioned by the scanty material available to him, Carlgren, 1951, gives but a brief description of *Epizoanthus gabrieli*. On the basis of his description alone we could not fully compare *E. leptoderma* with *E. gabrieli* and for this reason felt justified in further dissecting and sectioning a part of what remains of the holotype of *E. gabrieli*. Through this investigation we have obtained a little more information which we would like to offer here for incorporation with Carlgren's description and thus more fully describe and illustrate his species.

Epizoanthus gabrieli Carlgren
Figs. 10, 11

Epizoanthus gabrieli Carlgren, 1951, p. 438, pl. 14, fig. 6.

MATERIAL EXAMINED: Holotype, U.S. Nat. Mus. Cat. No. 49463, one colony of five polyps. From Gabriel Bay, Espíritu Santo Island, Baja California. Collected by E. F. Ricketts, April 12, 1940.

Carlgren's description of *E. gabrieli* has been found on re-examination to be accurate in the main. However, instead of "incrusted with

grains of sand occupying the main part of the mesogloea," we find that the incrustation is largely in the very thick ectoderm and is only sparsely present in the mesogloea. This slight discrepancy is likely due, in Carlgren's case, to the incrusting particles being carried into the mesogloea by a dull knife while sectioning. Although the polyps are small, they have a very thick column wall. The mesogloea is about five times as thick as the entoderm, and in turn the ectoderm is about two times as thick as the mesogloea.

The description of the sphincter muscle given by Carlgren, "strong, broad, transversely stratified," refers to the upper part only. He fails to mention that the sphincter tapers gradually to a long tail which is more alveolar than stratified (Fig. 10).

FIG. 10. Transverse section of the marginal sphincter muscle of *Epizoanthus gabrieli*. The higher epithelium is entoderm. Scale = .10 mm.

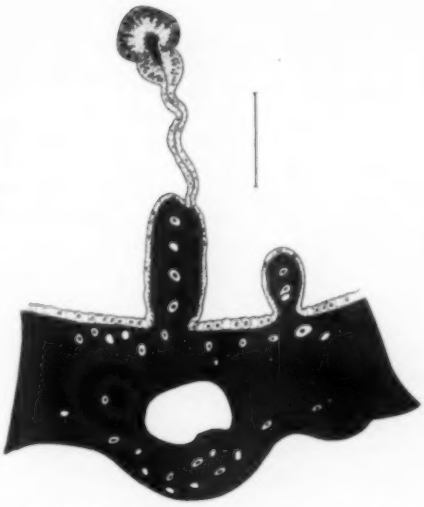


FIG. 11. Transverse section of a macro- and microcneme of *Epizoanthus gabrieli*. The large space in the column mesogloea is an artifact. Section taken from mid-column. Scale = .10 mm.

The mesenteries of the polyp cut by Carlgren number 30, but a second and slightly smaller one sectioned by us had 28. The mesogloeal lamellae of the mesenteries of *E. grabrieli* are greatly thickened near their attachment to the column wall (Fig. 11). In the case of the macrocnemes, the thickened portion extends about half way to the filamental edge. The microcnemes, on the other hand, because they do not bear filaments, are entirely thick. In section, the microcnemes are about half the length of the thickened portion of the macrocnemes. The mesogloea of the thickened parts of the mesenteries has much the same appearance as that of the column. The retractor muscles of the mesenteries are very weak.

REFERENCES

CARLGREN, OSKAR H. 1898. Zoantharien. Ergebnisse der Hamburger Magalhaensischen Sammelreise 1892, 1893. 1(4): 1–47, 1 pl., figs. 1–18. Hamburg.

——— 1920. Actiniaria und Zoantharia von Juan Fernandez und der Osterinsel. IN The Natural History of Juan Fernandez and Easter Island. Carl Skottsberg, ed. Vol. 3, pp. 145–160, text figs. 1–18, pl. 6, figs. 1–4.

——— 1927. Actiniaria and Zoantharia. IN Further Zoological Results of the Swedish Antarctic Expedition 1901–1903, under the Direction of Dr. Otto Nordenskjöld. Vol. 2, No. 3. Pp. 1–102, text figs. 1–62.

——— 1934. Über einige Ostasiatische Zoantharien. Ark. Zool. 28A(5): 1–11, text figs. 1–6.

——— 1951. The actinian fauna of the Gulf of California. Proc. U. S. Nat. Mus. 101 (3282): 415–449, text figs. 78–84, pl. 14, figs. 1–14.

DÜBEN, M. W., and J. KOREN. 1847. Om. nogle norske Actinier. Forh. Skand. Naturf. Møte. P. 266.

DUERDEN, JAMES E. 1900. Jamaican Actiniaria. Part 2: Stichodactylinae and Zoantheae. Sci. Trans. R. Dublin Soc. Vol. 7, ser. 2, part 6. Pp. 133–208, pls. 10–15.

GRAY, JOHN E. 1867. Notes on Zoanthinae, with the descriptions of some new genera. Proc. Zool. Soc. Lond. 15: 233–240, 1 text fig.

HADDON, ALFRED C., and ALICE M. SHACKLETON. 1891. A revision of the British Actiniae, Part 2. The Zoantheae. Sci. Trans. R. Dublin Soc. Vol. 4, ser. 2, part 12. Pp. 609–672, pls. 58–60.

HARVEY, E. NEWTON. 1952. Bioluminescence. xvi + 649 pp., 187 figs. Academic Press Inc., New York.

——— 1955. Survey of luminous organisms: Problems and prospects. IN Luminescence of Biological Systems. Frank H. Johnson, ed. Pp. 1–24, 1 table. A.A.A.S., Washington.

JOHNSTON, GEORGE. 1842. A History of British Sponges and Lithophytes. Vol. XII. 264 pp., 23 text figs., 25 pls. Edinburgh.

LE CONTE, JOHN L. 1851. Zoological notes. Proc. Acad. Nat. Sci. Philad. 5: 316–320.

LWOWSKY, FRITZ F. 1913. Revision der Gattung *Sidisia* Gray (*Epizoanthus* auct.). Zool. Jb., Abt. f. Syst. Vol. 34, parts 5, 6. Pp. 557–614, text figs. A-H and J-M, pl. 19, figs. 1–8, 1 map.

MCMURRICH, JAMES P. 1904. The Actiniae of the Plate Collection. Zool. Jb., Suppl. Bd. 6 (Fauna Chilensis Bd. 3) heft 2. Pp. 215–306, pls. 14–19.

SCHMIDT, OSCAR. 1862. Die Spongien des Adriatischen Meeres. vi + 88 pp., 7 pls. Verlag von Wilhelm Engelmann, Leipzig.

VERRILL, ADDISON E. 1866. On the polyps and corals of Panama, with descriptions of new species. Proc. Boston Soc. Nat. Hist. 10: 323–333.

——— 1869. Review of the corals and polyps of the west coast of America. Trans. Conn. Acad. Arts Sci. Vol. 1, part 2, no. 6. Pp. 377–558, pls. 4–10.

WOOD, RICHARD L. 1958. Identification and microanatomical study of a new species of *Epizoanthus* (Zoanthidea). Abstr. Diss. 18 (2): 707–708.

Notes on Ecology, Distribution, and Systematics of Pelagic Tunicata from New Zealand

B. M. Bary[1]

The Copelata and Cyclomyaria appear to be the only groups among pelagic tunicates to have been directly reported on for New Zealand, the former by Garstang and Georgeson (1935) and the latter by Garstang (1933). These reports resulted from collections of the "Terra Nova" Expedition. Thompson (1948) in a comprehensive treatise on "Pelagic Tunicates of Australia" refers only occasionally to New Zealand species.

Samples were collected from H.M.N.Z.S. "Lachlan" (Bary, 1956) to the south and east of New Zealand. *Oikopleura fusiformis* was captured mainly from cooler oceanic waters and is a new record for New Zealand. *O. dioica* occurred infrequently in warm coastal waters. Gonozooids and phorozooids of *Doliolum* (*Dolioletta*) *valdiviae* were obtained, and the "old nurse" stage is believed to have been identified. The remaining two orders, Pyrosomida and Desmomyaria, were also represented. *Pyrosoma atlanticum* was very abundant, especially in March and April, and *P. spinosum* was collected once as an incomplete colony. Both are apparently new records for New Zealand, and, in the case of *P. spinosum*, for Australia and the South Pacific as well (Metcalf and Hopkins, 1919; Thompson, 1948; Sewell, 1953). Of the five species of Salpidae (O. Desmomyaria) collected *Iasis zonaria* was rare; *Thalia democratica* was present at a few stations, but in very large numbers; one specimen of *Pegea confoederata* was captured; *Salpa fusiformis* f. *aspera* was common, and *Ihlea magalhanica* was very common.

MATERIALS AND METHODS

These have been detailed elsewhere (Bary, 1956, and 1959*a*, 1959*b*). Briefly, collections were made in near and offshore waters to the east and south of South Island, New Zealand (January to March, 1951) and southward to Auckland and Campbell islands (November, 1951) from H.M.N.Z.S. "Lachlan," a naval frigate on surveying duties. Tows, made predominantly in the surface layer (there were a few oblique tows), were of 3 minutes' duration at 1½ to 2 kt. with a net of 50 cm. diameter constructed with graded silks. Procedure was standardised and some quantitative analyses have been made. Surface temperatures were taken and salinities were determined for many of the plankton stations, and at other locations as well.

Temperature-Salinity-Plankton diagrams are again utilised (Bary, 1959*a*; 1959*b*) and they assist with the interpretation of the origins and distribution of species.

Previous Records from New Zealand

Four species of Copelata and four species of Cyclomyaria have been reported from the Terra Nova collections, made in the vicinity of Three Kings Islands, northern New Zealand. These are: *Oikopleura longicauda* Vogt, *O. rufescens* Fol, *O. dioica* Fol, *Stegosoma conogaster* Garstang and Georgeson, *Doliolum denticulatum* Quoy and Gaimard, *Dolioletta gegenbauri* Uljanin, *Doliolina mülleri* Krohn, and *Dolioletta mirabilis* (Korotneff).

Other species were collected by "Terra Nova" to the south of New Zealand. It is possible that these may extend northwards towards southern New Zealand either in subantarctic water or the deep Antarctic Intermediate water whence upwelling might bring them to the surface. These species and the regions from which they were collected are: *Oikopleura valdiviae*, from 64°–72° S., common; *Folia gigas*, Antarctic, rare; *Pelagopleura magna*, Antarctic (71° S.), rare; and *Doliolina intermedium* var. *resistible* Neumann, Antarctic, rare. Thompson (1948)

[1] N. Z. Defence Scientific Corps, c/o Navy Office, Wellington, N. Z. Now at Institute of Oceanography, University of British Columbia, Vancouver, Canada. Manuscript received April 8, 1958.

records five of the Terra Nova species from southeastern Australian waters, namely, *O. rufescens, O. dioica, O. longicauda, Dolioletta gegenbauri,* and *Doliolum denticulatum.* Thus, of the eight species recorded from the vicinity of New Zealand, two, *D. mülleri* and *D. mirabilis,* have not been recorded from Australia. The remainder are widespread in tropical and subtropical waters, and are common to the two countries.

The majority of tows of this present survey were in water of subantarctic origin in which fewer species occur (Thompson, 1942, 1948). However, further investigations in this water and a survey to the north of the subtropical convergence could not fail to be rewarding.

OBSERVATIONS ON SYSTEMATICS OF SPECIES

There is a long list of published literature on the complex systematics of the pelagic tunicata, and the following are representative: Ritter (1905), Salps, Doliolids, and Pyrosoma; Ritter and Byxbee (1905), Salps, Appendicularia, Pyrosoma; Aida (1907), Copelata; Metcalf (1918), Salpidae; Metcalf and Hopkins (1919), Pyrosoma; Essenberg (1926*a*), Copelata; Garstang (1933), Doliolids; Garstang and Georgeson (1935), Copelata; Thompson (1948), Sewell (1953), Copelata, Pyrosoma, Salpidae, and Doliolida. For bibliographies on each group, see Thompson (1948) and Sewell (1953). In view of these extensive works only brief notes are provided for most species in the following account, and only that literature actually cited is appended to the species.

Class I: COPELATA
Family OIKOPLEURIDAE
Genus OIKOPLEURA Mertens

Oikopleura fusiformis Fol.

Oikopleura fusiformis Aida, 1907; Essenberg, 1926*a;* Tokioka, 1940; Thompson, 1948

Over 4,000 specimens were collected from 10 hauls between Station 921 (51° 41′ S.) and the south of Cook Strait (43° 15′ S.), in January, 1951.

Characteristic features of the species are the long, slender fusiform body (Fig. 1) with straight, flat dorsal contour, and the long narrow tail without subchordal cells.

Specimens from four stations were measured and the data are presented in Table 1.

Sizes and ratios of the New Zealand specimens are similar to those given by, for example, Essenberg (1926*a*) for California, Russell and Colman (1935) for the Great Barrier Reef, and Thompson (1948) for southeast Australian waters (see Table 2).

Tokioka (1940: 2–3) briefly discusses and illustrates the considerable variability of shape in the blind-sac of the left stomach. Similar variations appear characteristic of this organ in the New Zealand material.

A feature of New Zealand specimens was the high proportion (in some catches all) of specimens without the oikoplast epithelium. Whether the epithelium usually is sloughed, along with the throwing off of the "house," when specimens are captured, is not made clear by Essenberg (1926*b*) in his discussion of the disintegration and decay of specimens. It is not invariably so, however, as on several occasions specimens without the house, but with the oikoplast epithelium intact, were collected.

Oikopleura dioica Fol.

Oikopleura dioica Aida, 1907; Essenberg, 1926*a;* Tokioka, 1940; Thompson, 1948

Specimens were collected from six stations, but occurrences were spasmodic. Stations 12, 21, 32, 40, and 48 (numbers collected were estimated) constituted a continuous series of catches in early January in coastal waters.

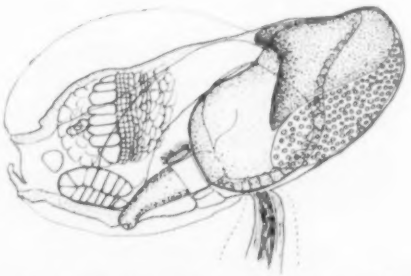


FIG. 1. *Oikopleura fusiformis,* a mature specimen of 0.9 mm. body length.

TABLE 1

THE RANGES AND THE RATIOS OF THE LENGTHS OF BODY AND TAIL OF *Oikopleura fusiformis* FROM NEW ZEALAND

STATION NO.	LENGTHS (MM.)				RATIOS, BODY TO TAIL		
	Body		Tail				
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Average
32	1.2	0.8	4.3	3.5	3.6	4.4	4.0
153	1.1	—	4.1	—	3.7	—	3.7
171	1.1	0.3	4.8	1.4	4.4	4.6	4.5
178	1.4	0.4	4.5	2.0	3.2	5.0	4.1
Averages					3.7	4.7	4.1

Oikopleura dioica (Fig. 2) is the only species so far described as being unisexual. This, together with a long tail with two subchordal cells, stout trunk, a characteristic posteroventral blind-sac to the right stomach, but absence of blind-sac on the left stomach, are features of diagnostic value (see Table 3).

Aida (1907) gives the body length of his largest specimen as 1111 μ, and the tail length as 3888 μ, i.e., a ratio of body to tail of 3.5; Essenberg (1926*a*) states that the body length ranges from 0.5 to over 1 mm., and that the tail is "about four times the length of the trunk." Thompson (1948) gives measurements of 0.3 to 1.2 mm. body length, 1.4–4.0 mm. tail length, the ratios of body to tail length being 4.7 and 3.3 respectively. Thus the New Zealand material corresponds well with that from elsewhere (excepting the ratio of 1:7.0 obtained for a small specimen with an abnormally long tail, captured at Station 12).

Class II: ACOPA (CADUCICHORDATA)
Subclass THALIACEAE
Order PYROSOMIDA
Family PYROSOMATIDAE
Genus PYROSOMA Peron

A detailed study of *Pyrosoma* by Metcalf and Hopkins (1919) is summarised and applied to Australian material by Thompson (1948). Sewell (1953) critically analyses these and other studies of the genus, and shows that many species and subspecies previously recognised are but growth stages of a relatively small number of species.

Two species were present in the New Zealand material. One damaged specimen of *P. spinosum* was collected at Station 326; *P. atlanticum* occurred between Cook Strait and southern New Zealand, sometimes in very large numbers.

Pyrosoma atlanticum (Peron)

Pyrosoma atlanticum Metcalf and Hopkins, 1919; Thompson, 1948; Sewell, 1953

Specimens from the tetrazooid to colonies 40 cm. long were present in moderate numbers, from the beginning of February. In March, and especially in April (collections partially

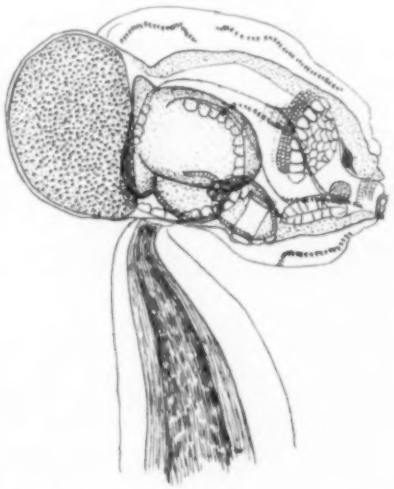


FIG. 2. *Oikopleura dioica*, a mature male of 1.1 mm. body length.

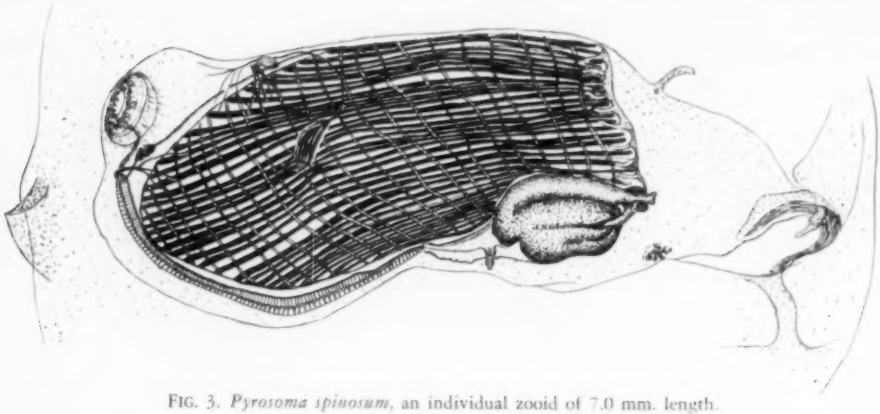


FIG. 3. *Pyrosoma spinosum*, an individual zooid of 7.0 mm. length.

analysed) very many thousands occurred off Dunedin and at several localities northwards of Dunedin.

In what proportions the *Pyrosoma* population should be divided between this, and the next species (*P. spinosum*) is not known. Thirty specimens, between the tetrazooid and large colonies, randomly selected from a number of samples, were closely examined and found to be *P. atlanticum*. And of many hundreds handled, only the one colony of *P. spinosum* was detected. *P. atlanticum* is therefore believed to predominate by a large majority.

Pyrosoma spinosum Herdman

Pyrosoma spinosum Herdman, 1888; Metcalf and Hopkins, 1919; Thompson, 1948; Berrill, 1950; Sewell, 1953

One colony secured at Station 326 constitutes a new record for New Zealand and Australia.

The zooid illustrated (Fig. 3) is 7 mm. extreme length. It possessed 23 gill bars, 35 rows of stigmata, and 9 languets, thus agreeing reasonably with numbers given by Sewell (1953) for a zooid of *P. spinosum* of 6.9 mm. (29–30 gill bars, 40 stigmata, and 6–8 languets). There is agreement with other accounts in respect of the position of the anterior light organs; in the number of atrial and cloacal tentacles and their positions; the ventrally split cloacal aperture; the dorsad curvature of the anterior part of the endostyle; in the posteriorly located languets; and in general shape and proportions.

Sewell discusses a "renniform body," originally reported by Metcalf and Hopkins (1919), and present in a sac situated in the test wall a little posteroventrally to the anus. From its similar location to the cyathozooid in *P. atlanticum* Sewell concludes this body is an early stage of a cyathozooid. He mentions that when this organ is present there is no trace of a testis.

A "renniform body" was not identified for certain in the New Zealand material. However, a small granular body appeared to be situated in the test wall, in the position described for the "renniform body." That this may have been Sewell's developing cyathozooid is suggested by this location, and the fact that no testis was present in the zooids examined.

Order CYCLOMYARIA
Family DOLIOLIDAE
Genus DOLIOLETTA Borgert
Dolioletta valdiviae Neumann

Dolioletta valdiviae Garstang, 1933

The majority of specimens were collected at Stations 74–85; a few occurred subsequently at Stations 109, 124, and 178.

GONOZOOID: Length, 2.0 to 8.2 mm. (Figs. 4, 5, 6).

There are 26 dorsal and 15 ventral lamellae in the gill septum. The dorsal septum extends from about M.3⅓ to M.6, and occasionally to M.6¼; the ventral septum extends forward to M.5. M.6 is of normal width dorsally and

TABLE 2

THE RANGES AND THE RATIOS OF THE LENGTHS OF BODY AND TAIL RECORDED FOR *Oikopleura fusiformis* FROM ELSEWHERE IN THE PACIFIC OCEAN THAN NEW ZEALAND

AUTHOR	LENGTHS				RATIOS, BODY TO TAIL LENGTH		
	Body		Tail				
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Average
Thompson	1.4	0.4	5.0	2.0	3.6	5	4.3
Russell and Colman	—	—	—	—	—	—	4
Essenberg	1.1	0.75	3.8	3.7	3.4	5.1	4.25

laterally, but narrows appreciably ventrally. The intestine forms a loose dextral coil; the anus is usually in a median position, but may be displaced slightly dorsally and to the right; the anus and the coil of the intestine lie between M.6 and M.7. The testis is coiled; it commences near the ovary, situated posterodorsally to the coil of intestine, runs forward to about M.5¼ on the left side, then loops back and curves behind and above the intestine, ending towards the right side where it is usually slightly enlarged. The endostyle runs from M.2½ to M.4½–4⅔. The nerve ganglion is situated at M.3⅓.

PHOROZOOID: Similar to the gonozooid in appearance and size (Fig. 7). It is without gonads and possesses a median posteroventral process between M.7 and M.8 which receives muscle slips from M.7.

Garstang (1933) suggests that *D. valdiviae* may be a form of *D. mirabilis* (Korotneff). He supports this with argument concerning developmental trends in the location of the testis and branchial septa relative to muscle bands. He says (p. 204) that "There is . . . a possibility . . . that the 'Specific' differences in the limiting attachments of the gill septum [between each of several pairs of species] are ultimately matters of differential growth rates and doubtless modifiable by nutrition, temperature, and similar environmental factors, as in other cases." Nevertheless he distinguishes *D. valdiviae* from *D. mirabilis* (= *chuni*) by the different positions of attachment of the ventral septum and the extension behind M.6 of the septum, together with the length of the endostyle and the coiling of the testis (see Garstang, p. 216, fig. 5), and the fact that in *D. mirabilis* M.6 is incomplete ventrally, which is "without precedent" (p. 221). Sewell (1953: 53) regards the two gonozooids he collected as combining certain characters of both *D. valdiviae* and *D. mirabilis:* "In the length of the endostyle and the interrupted VIth body muscle, they conform to *D. mirabilis,* but the position and arrangement of the testis comes more nearly into line with the description of *D. valdiviae.* The ending of the gill lamella ventrally at the Vth muscle band agrees with *D. valdiviae,* whereas in *D. mirabilis* it is continued forward to the level of the IVth body muscle." He inclines to

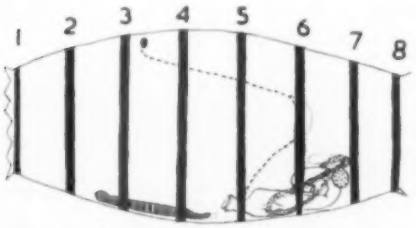


FIG. 4. *Doliolum (Dolioletta) valdiviae,* diagram of the gonozooid to illustrate the chief diagnostic features. M1 to M8, body muscles.

FIG. 5. *Dolioletta valdiviae,* gonozooid of 3.9 mm. length.

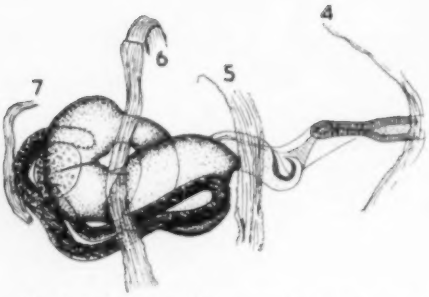


FIG. 6. *Dolioletta valdiviae*, ventral view of gut and gonads of gonozooid. M4 to M7, body muscles.

the belief that *D. valdiviae* may be a form of *D. mirabilis*.

From Sewell's account, it would seem that the "position and arrangement of the testis" is the only character preventing him from identifying his specimens as *D. mirabilis*. Garstang has discussed testis growth and the considerable variations in its shape and position resulting from differences in the reaction to muscle bands of its anterior termination. This applies especially in *D. denticulatum*, but also in *D. gegenbauri* and *D. tritonis*. The growth of the testis in these species, he states, is parietal, which involves penetration in the body wall between the pharyngeal epithelium and successive muscle bands: the connections of muscles to the pharyngeal epithelium constitute definite obstacles to advance. An obstinate barrier to penetration may cause the terminal portion to loop back or otherwise alter direction. Of *mirabilis*, Garstang says, the testis begins as a parietal organ while in *valdiviae* it does not. It is possible, therefore, that Sewell's specimens demonstrate an abnormal condition of the testis, due to some check during growth, with a consequent similarity to the testis of *valdiviae*. It would seem, otherwise, that the specimens are *mirabilis*. Nevertheless, as Garstang says (p. 219), "An origin of *valdiviae* from *mirabilis* by a precocious differentiation of connective tissues impeding the advance of the gill septum and the parietal growth of the testis is still conceivable."

The New Zealand material agrees with Garstang's account of *D. valdiviae* in possessing an entire, but narrowed M.6 (Fig. 7) and in the coiling of the testis about the intestine. On the other hand, Garstang illustrates the dorsal septum extending to M.6½ and the endostyle almost from M.2 to close to M.5, whereas in the New Zealand material the septum usually extended only to M.6 (once to M.6¼) and the endostyle between M.2½ to M.4½–M.4¾ (Figs. 4, 5). Although these two features bear more similarity to *D. mirabilis*, Garstang has pointed out (pp. 204, 217) that variation in the extent of both organs does occur and consequently they may not be important to the proposition that the New Zealand material is *D. valdiviae*.

OLD NURSE STAGE: Garstang (1933) successfully differentiates between the "nurse" stages of *D. gegenbauri* and *D. mulleri* by comparison of the proportional widths of the individual muscle bands when the width of each band is expressed as a percentage of the total muscle width. He finds that in *D. gegenbauri*, M.3 and M.4 dominate (with M.3 of slightly higher percentage width than M.4), and in *D. mulleri*, M.4 and M.5 are dominant. The distinctions were valid

TABLE 3

THE RANGES AND THE RATIOS OF THE LENGTHS OF BODY AND TAIL OF *Oikopleura dioica* FROM NEW ZEALAND

STATION NO.	LENGTHS (MM.)				RATIOS, BODY TO TAIL LENGTH		
	Body		Tail				
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Average
12	1.1	0.5	3.8	3.4	3.75	7.0	5.4
32	0.9	0.7	3.9	3.1	4.3	4.4	4.35
40	1.4	1.0	5.1	3.6	3.7	3.6	3.65
Averages					3.9	5.0	4.5

TABLE 4

WIDTHS OF M2 TO M8 EXPRESSED AS PERCENTAGE OF TOTAL MUSCLE WIDTH IN "OLD NURSES" FROM NEW ZEALAND

LENGTH OF SPECIMEN	TOTAL MUSCLE	WIDTH OF MUSCLES AS PERCENTAGES OF TOTAL MUSCLE						
mm.	mm.	M2	M3	M4	M5	M6	M7	M8
9.8	7.3	12.3	19.2	17.8	15.1	13.7	12.3	9.6
10.0	9.9	12.7	17.9	18.9	15.2	13.8	11.4	10.1
10.5	7.7	14.3	18.2	16.9	15.6	15.6	11.6	7.8
10.6	6.9	14.5	17.4	17.4	15.8	14.5	13.1	7.3
11.0	8.1	12.3	19.9	18.6	16.1	13.3	12.3	7.5
12.0	9.7	14.5	20.6	18.5	13.4	12.4	11.4	9.2
13.5	11.5	16.5	17.3	17.4	15.7	13.9	10.5	8.7
13.8	12.1	14.8	19.0	16.5	15.7	13.2	12.5	8.3
15.4	13.6	13.8	21.3	16.8	14.6	13.8	12.4	7.3
17.5	12.0	15.8	17.5	17.5	15.9	12.5	12.5	8.3
21.0	17.7	13.0	19.3	17.7	16.5	15.3	11.9	6.3
22.0	16.4	13.4	18.3	18.3	14.0	14.0	12.2	9.8
23.0	17.4	13.8	17.2	17.1	16.7	14.4	14.4	6.4
28.0	18.6	14.7	16.7	17.6	16.4	14.6	13.4	6.6
29.0	15.75	14.5	18.4	18.5	14.5	13.5	12.9	7.7
33.5	24.05	12.6	19.6	17.1	15.9	14.7	12.6	7.5
Averages		14.0	18.6	17.7	15.4	14.0	12.3	8.0

for specimens from all areas sampled, including New Zealand.

Old nurse stages (Fig. 8) occurred in the present material along with the gonozooids and phorozooids of *Dol. valdiviae*. Application of Garstang's method to specimens indicates there is affinity to the "*gegenbauri* type." Consistent differences from his material were evident, however, in the percentage widths of M.2, and M.6 to M.8, relative to the widths of M.3 and M.4, see Tables 4 and 5. Table 4 presents data from Lachlan material, and Table 5, from Garstang, for *D. gegenbauri*. As M.1 and M.9 were difficult to measure accurately because of variability in the state of contraction, and also were frequently damaged, they are omitted. The omission is scarcely significant, amounting in all to some 2–3 per cent (Garstang, p. 234), and does not account for the differences between the two groups of specimens.

In Lachlan material, M.2 averages 3.7 higher than in *D. gegenbauri*, M.3 and M.4 are respectively 1.0 and 0.7 lower, M.5 about the same, M.6 somewhat lower, but M.7 shows an increase of 1.2 and M.8 an increase of 2.4. Thus the New Zealand specimens are distinguishable by the greater proportional widths of M.2, M.7 and M.8 relative to M.3 and M.4.

TABLE 5

WIDTHS OF INDIVIDUAL MUSCLES AS A PERCENTAGE OF TOTAL MUSCLE WIDTH, FOR "OLD NURSES" OF *D. gegenbauri* (FROM GARSTANG)

LENGTH	MUSCLE	WIDTH OF MUSCLES AS PERCENTAGES OF TOTAL MUSCLES								
mm.	mm.	M1	M2	M3	M4	M5	M6	M7	M8	M9
3– 9	—	4.0	9.6	18.1	17.8	15.2	14.2	11.2	6.3	3.4
2– 6	—	1.8	9.9	18.3	18.3	16.2	14.9	12.0	6.2	2.4
6–18	—	2.7	10.6	20.3	18.6	15.1	14.1	10.7	5.2	2.8
6– 7	5.1	2.6	10.5	19.7	18.3	15.1	13.8	11.4	5.6	3.0
9–15	10.3	2.8	10.8	20.6	18.5	15.1	14.1	10.4	5.2	2.7
17–18	14.7	2.5	10.7	20.5	18.9	15.1	14.2	10.7	4.7	2.6
Averages		2.7	10.3	19.6	18.4	15.3	14.2	11.1	5.6	2.8

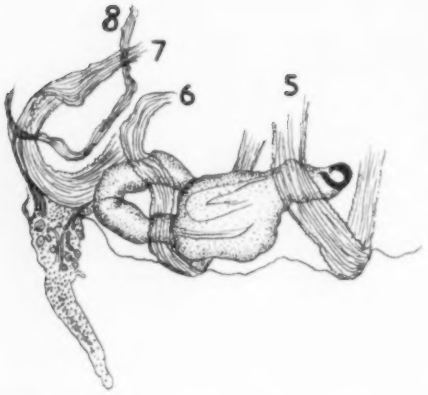


FIG. 7. *Dolioletta valdiviae*, stomach, intestine and ventral process of phorozooid.

For the specific distinctions to be maintained, reliance is being placed on differences of proportional widths of muscle bands. It is probable that the amphiclinous condition with the myoplane (Garstang's terminology) between M.3 and M.4 would persist among other species of a particular subgenus (in this instance *Dolioletta*); and, within the condition imposed by this, it is probable also that species may be distinguishable by differences in the proportional widths of muscle bands, much as different relative widths of muscles, combined with a change in position of the myoplane, occurs between *Dolioletta* and *Doliolina*.

The occurrence together of "old nurses," gonozooids, and phorozooids does not necessarily constitute evidence of identity. However, the "old nurses" from New Zealand consistently differ from those of a second species in the subgenus, and it is reasonable to suppose in the absence of other Doliolids, that the nurses, gonozooids, and phorozooids belong together. It is proposed that they be considered as those of *Dolioletta valdiviae*.

Garstang has been concerned that specimens from the area of the Benguela Current which he called *D. valdiviae* might be traceable to "Some 'abnormality' of growth conditions . . ." and that "the whole of the *valdiviae* stock may have been the produce of a single swarm of nurses reared under peculiar conditions of temperature and food supply." With the finding of specimens from New Zealand similar to those Garstang discusses, this possibility is reduced. That closely similar conditions of temperature and food supply prevailed in the two regions, and that reactions to these of the produce of some old nurses were the same, while not impossible, is unlikely.

Order DESMOMYARIA
Family SALPIDAE
Genus IASIS (Lahille)
Iasis zonaria (Pallas)

Salpa nitida Herdman, 1888
Salpa zonaria cordiformis Ritter, 1905
Salpa zonaria Metcalf, 1918; Thompson, 1948; Sewell, 1953

Fourteen specimens were collected from five stations, between Cook Strait (January) and Station 826, in the subantarctic.

Metcalf (1918) and Thompson (1948) describe and discuss this species at length. Figures 9 and 10 indicate the chief diagnostic features of the solitary and aggregate forms. As well, in solitary forms, the test is rigid, the muscles are broad and interrupted ventrally, and the body is symmetrical. In aggregate forms, the test is rigid, the muscles are widely interrupted ventrally, and the body is asymmetrical. Often one or more embryos are contained within the body.

The largest specimen was 63 mm. long, the smallest, 29 mm.

Genus THALIA Blumenbach
Thalia democratica Forskal

Thalia democratica mucronata Herdman, 1888

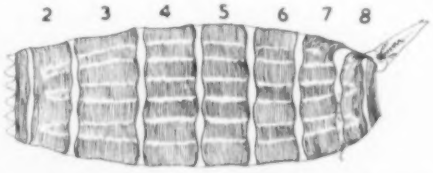
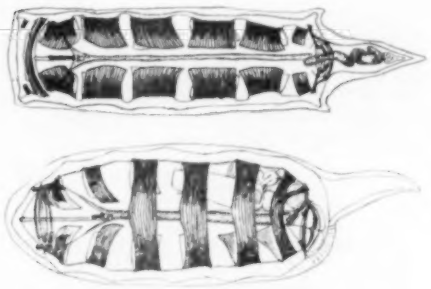


FIG. 8. The proposed "old nurse" of *Dolioletta valdiviae*, a 29 mm. specimen.



FIGS. 9, 10. *Iasis zonaria*, solitary and aggregate forms.

Salpa democratica mucronata Ritter, 1905; Ritter and Byxbee, 1905

Thalia democratica Metcalf, 1918; Thompson, 1948; Sewell, 1953

Initial collections of several hundred specimens were made at Stations 292, 301, and 304. Twelve days later, many thousands were collected from Stations 322 and 326, south of Cook Strait, in both surface and oblique tows.

The test is thickened, and often with protuberances. In solitary forms (Fig. 11) the muscles are continuous ventrally. Posteriorly the test protrudes in two long (up to the length of the body) and several smaller processes. In aggregate forms (Fig. 12) the test is greatly thickened, and with intruding tubular processes. The muscles are widely interrupted ventrally.

Solitary forms (including processes) ranged from 9.5 to 27.0 mm., and aggregate forms, from 4 to 16.5 mm. in length. Among the aggregate forms, an estimated 4 per cent possessed tests up to four times thicker than usual which made the body large and almost spherical.

Genus PEGEA Savigny
Pegea confoederata Forskal

Salpa quadrata Herdman, 1888

Salpa confoederata scutigera Ritter, 1905; Ritter and Byxbee, 1905

Pegea confoederata Metcalf, 1918; Dakin and Colefax, 1940; Fraser, 1947; Thompson, 1948; Sewell, 1953

One specimen, a solitary form (Fig. 13) occurred in an oblique (100-0 m.) haul at Station 326.

The specimen was approximately 35 mm. long, but was somewhat damaged anteriorly. The test is fairly rigid, especially in the portion about the alimentary "nucleus." Four dorsal muscles are arranged in two pairs, forming "X's"; neither pair reaches the lateral margins of body. Ventral muscles are absent.

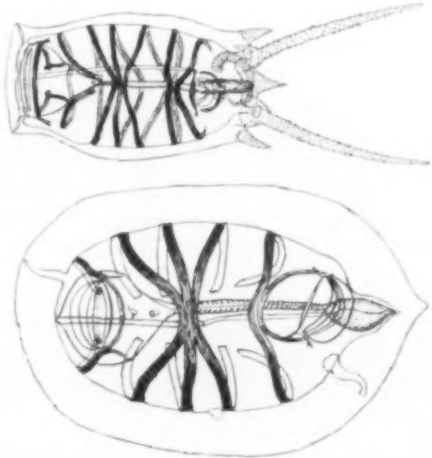
It is perhaps unusual that the only specimen captured should be the solitary form when it is recorded as rarer than the aggregate form (Ritter, 1905; Ritter and Byxbee, 1905; Metcalf, 1918; Thompson, 1948). Sewell, on the other hand, saw numerous solitary forms in the Gulf of Aden and indicates they were probably brought to the surface from deeper water by upwelling. The species is a warm water one (Thompson, Sewell) and occurred together with subtropical Copepoda, e.g., *Sapphirina* spp. in the New Zealand sample.

Genus SALPA Forskal
Salpa fusiformis f. **aspera** Chamisso

Salpa echinata Herdman, 1888

Salpa fusiformis f. *echinata* Ritter, 1905

Salpa fusiformis f. *aspera* Metcalf, 1918; Thompson, 1948



FIGS. 11, 12. *Thalia democratica*, solitary and aggregate forms.

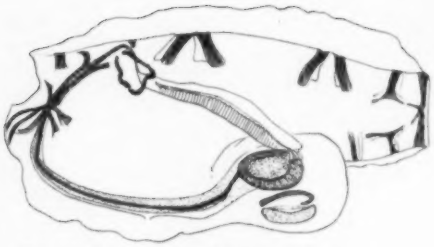


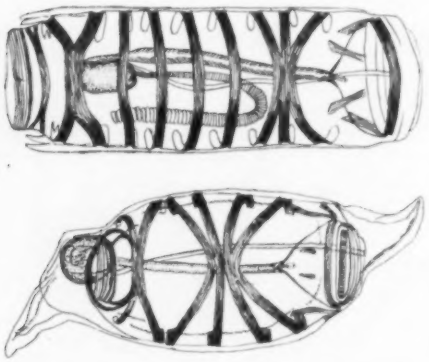
FIG. 13. Solitary form of *Pegea confoederata*.

A total of 463 specimens, of which 300 occurred at Station 826, were collected from eight stations between Cook Strait (January, 1951) and the subantarctic.

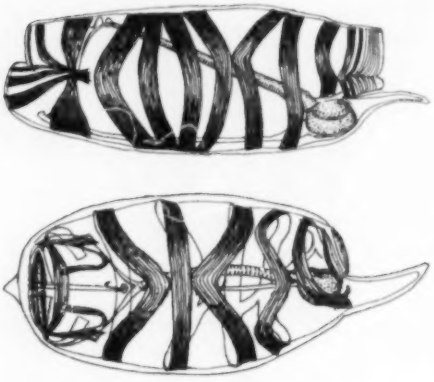
Figures 14 and 15 illustrate the chief features of the species. In the solitary form (Fig. 14) the test is flaccid anteriorly, more rigid posteriorly and with several short projections. Body muscles I–III and VIII–IX are in contact dorsally, the remainder are parallel. In the aggregate form (Fig. 15) the test is more or less rigid, with elongate anterior and posterior processes. Body muscles I–IV are in contact dorsally, and IV–V laterally.

The f. *aspera* is distinguished from *fusiformis s. str.* by the ridged and spinose character of the test and processes, although on some specimens it is inconspicuous, and they could readily be mistaken for smooth forms.

Only specimens of f. *aspera* were collected by the "Lachlan."



FIGS. 14, 15. *Salpa fusiformis* f. *aspera*, solitary and aggregate forms.



FIGS. 16, 17. *Ihlea magalhanica*, solitary and aggregate forms.

Genus IHLEA Metcalf

Ihlea magalhanica Apstein

Ihlea magalhanica Thompson, 1948

Specimens were common in the shallow waters of Foveaux Strait and northward to Dunedin; a few occurred at Station 326, south of Cook Strait.

The test is flaccid in both forms. The solitary form (Fig. 16) has a stout, conical process posteriorly on the test. There are seven body muscles. M.I–M.IV touch, but do not fuse, dorsally and ventrally; M.IV and V touch laterally and V and VI dorsally. The test of the aggregate form (Fig. 17) has a short anterior and longer posterior process, and the body is decidedly asymmetrical. There are five body muscles. M.I–III touch dorsally and M.III and IV almost touch dorsolaterally; M.II and III, III and IV, IV and V are connected medioventrally by anastomoses; M.V is incomplete ventrally.

DISTRIBUTION AND ECOLOGY OF SPECIES

Oikopleura fusiformis

Oikopleura fusiformis is usually described as inhabiting warm, oceanic waters, although according to Thompson (1948), Lohmann obtained it in Plankton-Expedition samples from waters of 3 to 37.4 ‰ salinity, and temperatures of 9.3° to 29.5°C. The salinity range of Lachlan material (Fig. 22) is 34.15 to 34.63 ‰. The lowest temperature at which

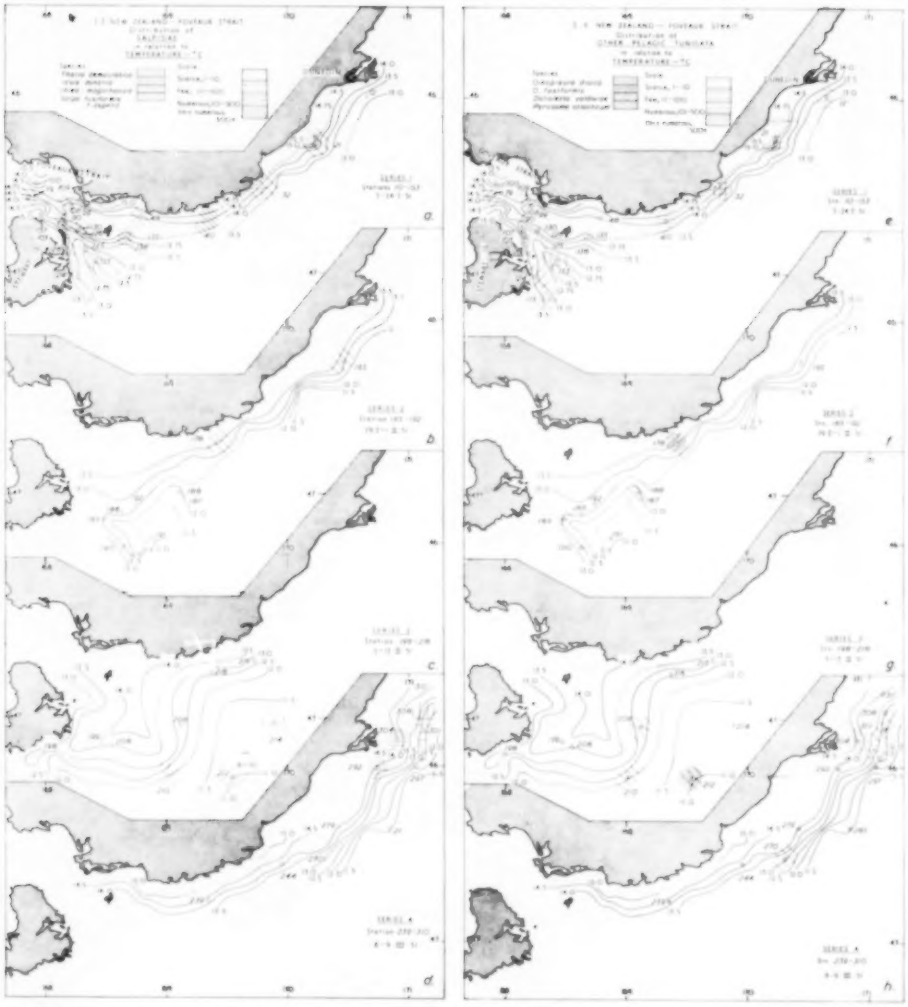
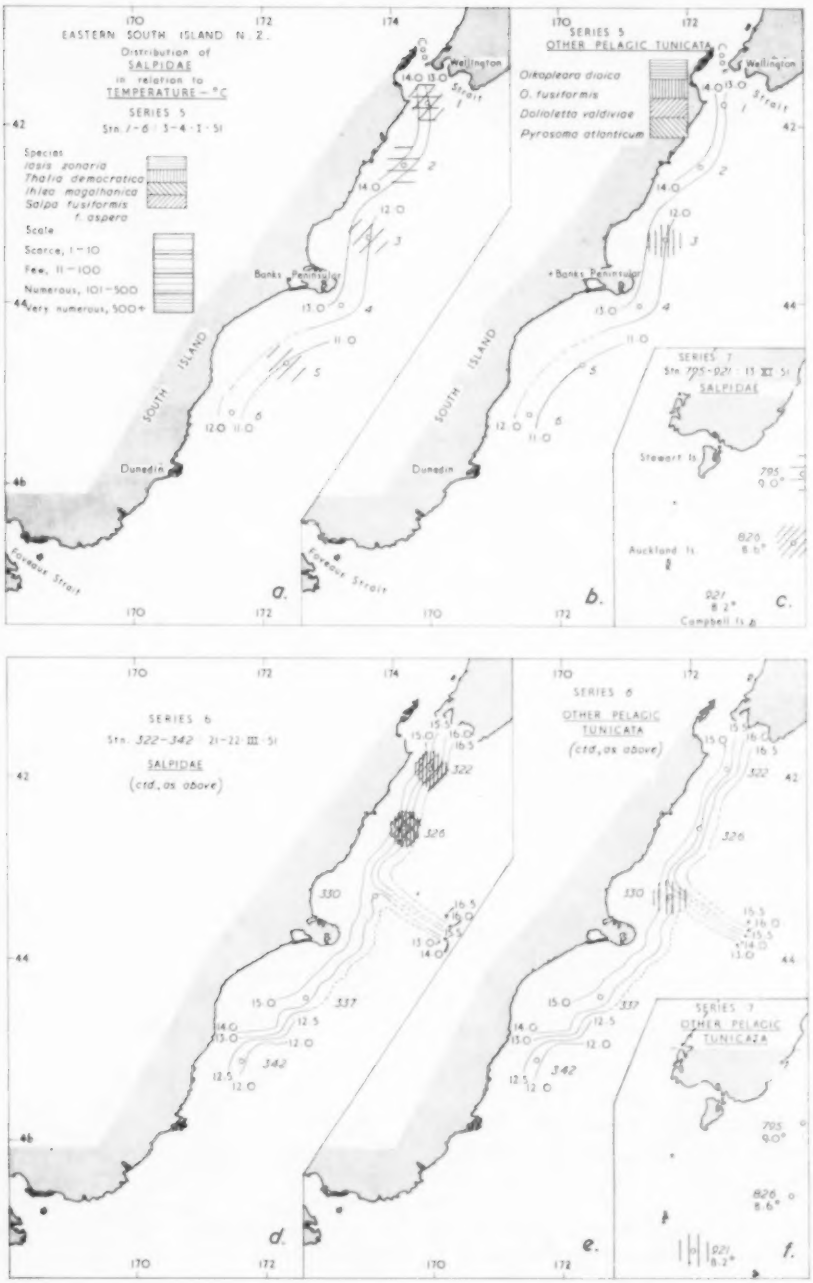


FIG. 18. Occurrences and distribution of pelagic tunicates, in relation to temperature, about southeastern New Zealand. *a–c*, Salpidae; *e–f*, other tunicates.

specimens were collected was 8.2°C. at Station 921, which is 1.1°C. lower than given by Thompson. As all the specimens were disintegrating (Essenberg, 1926*b*) it is possible that they had been carried into water below the lower limits of the temperature tolerance of the species.

The infrequent and sporadic occurrences of the species preclude a completed picture of local distribution. The charts in Figures 18 and 19 suggest it is being transported into coastal areas in intruding oceanic waters of subantarctic origin. Tokioka (1940) regards it as "this pure oceanic form," and the plot of its occurrence


EASTERN SOUTH ISLAND N. Z.
Distribution of
SALPIDAE
in relation to
TEMPERATURE – °C
SERIES 5
Species
Iasis zonaria
Thalia democratica
Ihlea magalhanica
Salpa fusiformis
f. aspera
Scale
Scarce, I – 10
Few, II – 100
Numerous, 101 – 500
Very numerous, 500+
SERIES 5
OTHER PELAGIC TUNICATA
Oikopleura dioica
O. fusiformis
Doliolella valdiviae
Pyrosoma atlanticum
SERIES 7
SALPIDAE
Stewart Is
Auckland Is
Campbell Is
SERIES 6
SALPIDAE
(ctd., as above)
OTHER PELAGIC TUNICATA
(ctd., as above)
SERIES 7
OTHER PELAGIC TUNICATA
Wellington
Banks Peninsula
SOUTH ISLAND
Dunedin
Foveaux Strait
a.
b.
c.
d.
e.
f.

against temperature and salinity (Fig. 22) bears this out. Over-all occurrences conform to the area of chief concentration being coincident with that of the "Southern" Subantarctic species (Fig. 20), but on the other hand, highest numbers were present in the area of the "Northern" Subantarctic species. The narrow limits of salinity (34.15 to 34.63 ‰) in which it is present are within those of subantarctic water (Deacon 1937). The temperature range of 8.2° to 14.5°C. is indicative of some degree of tolerance, but it would appear that specimens are being carried into the warmer coastal waters (e.g., Stations 330, 304) in water of subantarctic origin. The very numerous specimens at Station 178 are in coastal water, but evidence from occurrences of other species suggests that mixing may have taken place in this vicinity at an earlier time. Specimens possibly are resident in the subantarctic water (compare *Thysanoessa gregaria;* Bary, 1959*a*) which would extend the usual "warm-water" habitat to include a "cool-water" habitat about southern New Zealand. On the other hand, the species may have been carried southward from warmer northern waters, e.g., from the Tasman Sea. The disintegrating specimens from Station 921 lend support to such a suggestion.

Oikopleura dioica

O. dioica usually inhabits mixed, tropical and warm waters, but prefers coastal areas to the open ocean (Essenberg, 1926*a*: 486; Thompson, 1948: 39). The few occurrences in Lachlan samples also indicate adherence to coastal waters (Fig. 18*e*, and see Bary, 1959*a*). Temperatures are usually higher than for *O. fusiformis* (Fig. 22). It is believed that when *O. dioica* was collected with *O. fusiformis* (Stations 79, 330) (or when it occurred in water of similar properties to that from which *O. fusiformis* was captured) it was the result of coastal water having become mixed with water of subantarctic origin.

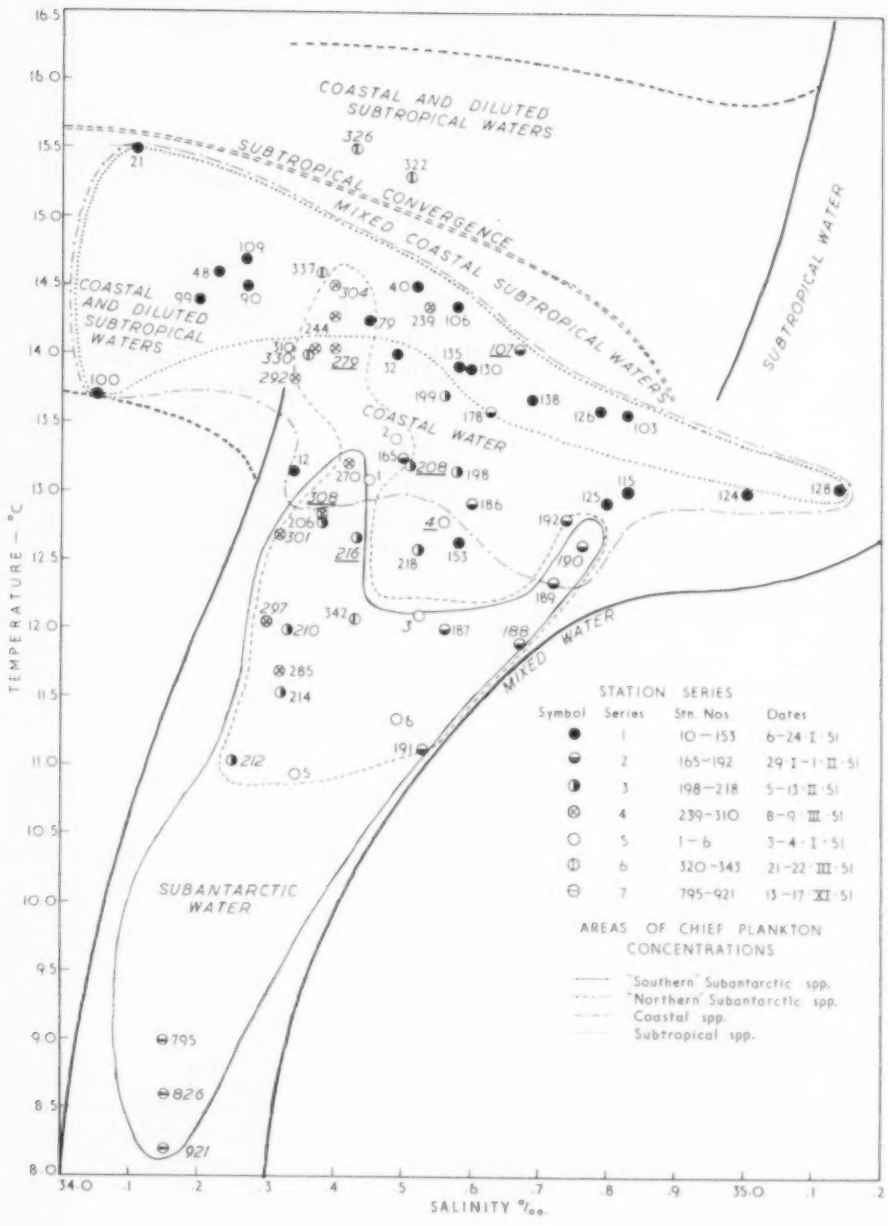
For neither *O. dioica* nor *O. fusiformis* from New Zealand is there enough information to show whether there is variation of numbers during January, February, and March, nor whether their distributions are related to the depth of water as one proceeds offshore (Bary, 1959*b*).

Pyrosoma spp.

Very extensive shoals of *Pyrosoma,* almost entirely *P. atlanticum,* were encountered between 10 and 20 miles seawards from Dunedin in late March and during April, 1951. Almost all specimens were aggregated into long lanes, or smaller or larger patches (Bary, 1953). Patches and lanes might occur over an extensive area at the surface, but when proceeding through a particular concentration, the colonies were seen to become progressively deeper in the water, eventually passing from sight. Oblique tows consistently collected large numbers, however, which suggests that the concentrations of specimens continued at depth. Such a vertical and horizontal distribution bears a striking resemblance to the hypothetical distribution of swarms of salps proposed by Hardy (1936: 519, fig. 7), and is of interest in relation to Sewell's (1953: 85) comment that *P. atlanticum* is "most common at some depth below the surface." The concentrations continued over several days, sometimes a number being present, at others, only one or two. Similar large shoals have been reported on several occasions from about Cook Strait. It is possible therefore they are a regular summer feature, at least along the eastern South Island coast.

The stomach contents of two fish, Blue Cod and Hapuku (*Parapercis colias* and *Polyprion oxygeneios*), caught by hand line off Stewart Island in February, confirmed fishermen's reports that *Pyrosoma* (the so-called "jelly" or "oatmeal") was common in late summer and autumn, to the extent that their catches were often depleted through the fish "being overfed and not biting." Of several hundred cod stomachs examined all but a few contained *Pyrosoma,* to about 8 cm. long. The colonies therefore must be counted as an important, although only seasonally abundant, fish food in this area. Off Dunedin, very large shoals of fish were present at the surface among the *Pyrosoma* aggregations, but it could not be verified that *Pyrosoma* was in fact being taken as food.

FIG. 19. Occurrences and distribution of pelagic tunicates in relation to temperature, between Wellington and the Auckland–Campbell Islands, New Zealand.


COASTAL AND DILUTED SUBTROPICAL WATERS
SUBTROPICAL CONVERGENCE
MIXED COASTAL SUBTROPICAL WATERS
SUBTROPICAL WATER
COASTAL AND DILUTED SUBTROPICAL WATERS
COASTAL WATER
MIXED WATER
SUBANTARCTIC WATER
TEMPERATURE — °C
SALINITY °/oo
STATION SERIES
Symbol Series Stn. Nos. Dates
1 10—153 6-24·I·51
2 165—192 29·I—1·II·51
3 198—218 5—13·II·51
4 239—310 8—9·III·51
5 1—6 3—4·I·51
6 320—343 21—22·III·51
7 795—921 13—17·XI·51
AREAS OF CHIEF PLANKTON CONCENTRATIONS
"Southern" Subantarctic spp.
"Northern" Subantarctic spp.
Coastal spp.
Subtropical spp.

Charts of the occurrences of *P. atlanticum* (Fig. 18*f–h*) indicate that it may be entering coastal areas in water of subantarctic origin, but when plotted against salinity and temperature (Fig. 22) the collections are seen to occur indiscriminately in coastal and "Northern" Subantarctic waters. Specimens were also collected from stations near Station 826 (not recorded herein) in the subantarctic. Such occurrences agree with Sewell (1953: 85) who says that *P. atlanticum* is common throughout the oceans between temperatures of 7° and 30°C.

Doliolum (Doliolet:a) valdiviae

Dolioletta valdiviae was present in that part of Foveaux Strait (Fig. 18*e, f*) in which coastal water is believed to be most directly influenced by water of subtropical origin (Bary, 1959*a*). Its few occurrences when plotted against salinity and temperature (Fig. 22) are in the warmest water, which together with its absence from samples elsewhere about southern New Zealand, suggest a warm-water origin for the species. More data on occurrences of the species about New Zealand and information on its distribution elsewhere are needed.

Iasis zonaria

This is a widely distributed species which Sewell (1953) regards as being carried from tropical to colder waters by currents. However, Thompson (1948) believes the species is more usually found in the deeper, colder waters in tropical or subtropical regions. It was plentiful off southeastern Australia (Thompson), but was commonest from the temperate waters of the Tasmanian area. In each year from 1939 to 1941 it decreased towards the north and this was interpreted as resulting from the increasing effects of subtropical conditions northwards. Russell and Colman (1935) recorded one specimen of the solitary form from 200 m. outside the Barrier Reef; Dakin and Colefax (1940) recorded specimens for September only, which is in agreement with Thompson's statement that the period of greatest abundance is in the spring (August or September to November or December).

Iasis zonaria is scarce in Lachlan samples (Fig. 18*d*). Occurrences, when plotted against salinity and temperature (Fig. 21) indicate a restricted range of salinity (ca. 34 ‰ to 34.5 ‰) and a preference for lower temperatures, features suggesting the species was collected from water of subantarctic origin. This would lend support to Thompson's belief that the species is a temperate-water one. The New Zealand records are too few to be more than suggestive.

Thalia democratica

Metcalf (1918) distinguishes between western Pacific and Atlantic forms of aggregate specimens of *Thalia democratica*. The Pacific form possesses a variable number of tubular test processes, and the test is rounded posteriorly to the alimentary "nucleus." The Atlantic form possesses few, and shorter, tubular processes and the test is pointed posteriorly. Sewell (1953) points out, however, that the test varies considerably among his specimens from the Indian Ocean. The Lachlan specimens had from zero to several tubular processes, most of which were short; none possessed a posterior process approaching the length illustrated by Metcalf for specimens from the Philippine Islands. This, and the pointed test posterior to the "nucleus" suggest they may have been of the "Atlantic" form. Thompson (1948) reported that the "West Pacific" form predominated in a collection from Kaipara Harbour, northwestern North Island, and it has since been collected in Hauraki Gulf on the east coast of North Island (unpublished data). Northern New Zealand is predominantly influenced by subtropical waters (and on the east coast, possibly even by water of tropical origin) and probably this form has been transported into these areas in these waters. In the south, the water is cooler and preponderantly of subantarctic origin. The distinctions in the shapes of the tests between north (Thompson's

FIG. 20. Generalised Temperature-Salinity-Plankton diagram of the sampled area. Only the plankton stations are shown; they are differentiated into series of stations which in turn are shown individually in Figures 18, 19. "Areas of chief concentration" (as demonstrated by all of the indicator species utilised) are also shown. Station numbers *in italics* are night stations; in italics and *underlined*, are dawn or dusk stations; unmarked are daylight stations.

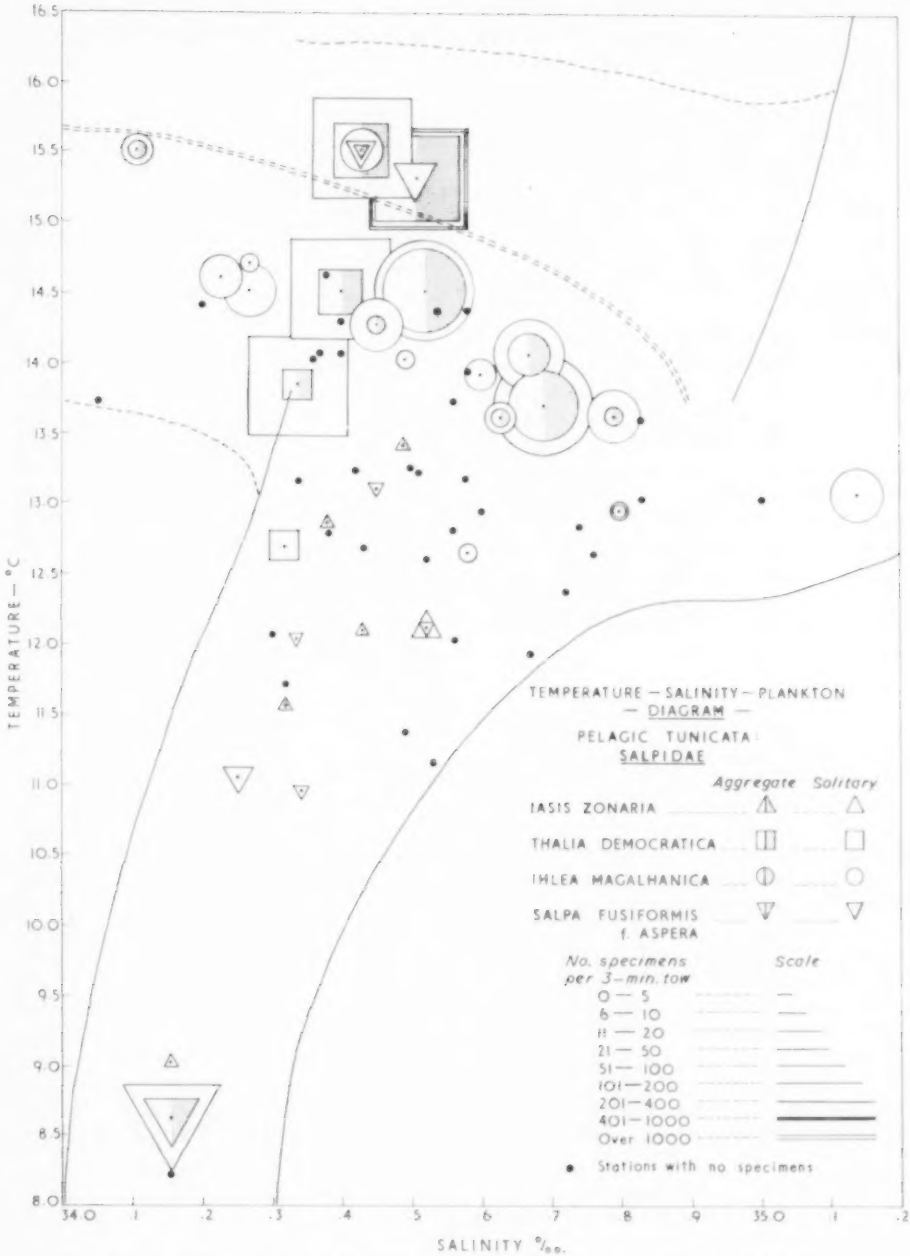


FIG. 21. Temperature-Salinity-Plankton diagram showing occurrences of species of Salpidae.

specimens) and south (Lachlan specimens) may thus result from the different environmental conditions.

The species made a sudden appearance, in large numbers, off Dunedin in early March (Fig. 18*d*). Twelve days later several thousands of specimens were taken from near Cook Strait in waters of subtropical origin. There was a complete absence of specimens in either surface or oblique tows between the areas. Morphological distinctions of a consistent nature could not be shown between these groups. Nor was it possible to demonstrate whether the concentrations were of similar origin. The plot of occurrences against salinities and temperatures (Fig. 21) indicates that the species was collected from a narrow range of salinity and from the warmest water. Indications are that the species is a warm-water one, which would be in accord with previously known facts of its distribution. For example, Thompson (1942, 1948) states that *T. democratica* occurred between temperatures of 11.0° and 25.6°C., but in very much smaller numbers in the cooler Tasmanian waters (limit, 44°S.) than in waters further north. Although New Zealand collections were from further south than those in Australia the lowest temperature was about 12.75°C. which is above the lower limit given by Thompson.

Salpa fusiformis f. *aspera*

Metcalf (1918) records *S. fusiformis* f. *aspera* as widespread in Atlantic, Pacific, and Indian oceans, from equatorial waters to those of high latitudes. Thompson (1948) records four specimens of f. *aspera*, but very large numbers of *S. fusiformis* from southeast Australia (he also took *S. fusiformis* from stomachs of "blue cod" (*Parapercis colias*) caught in western Cook Strait, New Zealand, in 1940). Lachlan specimens were entirely f. *aspera*, which reverses the order of catch recorded by Thompson, and is in line with Metcalf's statement that *aspera* was more abundant than the smooth form in his catches.

Specimens were collected from Cook Strait (in January) to the subantarctic (Station 826) where a considerable catch was made (Figs. 18*c*; 19*c*, *d*). The occurrences, plotted against salinity and temperature (Fig. 21), show that specimens were captured from salinities commensurate with those of water of subantarctic origin. They occurred over a wide range of temperature, but even so, the T-S-P diagram strongly suggests a subantarctic origin. Both temperature and salinity ranges include Stations 322 and 326. Specimens at these stations, which are north of the subtropical convergence, may have reached the surface from water of subantarctic origin lying below the surface subtropical water (Bary, 1959*a*).

Ihlea magalhanica

This species was present in very large numbers off southeast Australia, with highest concentration off eastern Tasmania where it replaced *Th. democratica* (Thompson, 1948). Thompson also recorded it as the only salp from a collection made in 1942 from northern South Island, New Zealand. Previous to these records, it was regarded as rare, being known only from the Cape of Good Hope and Strait of Magellan, from near Kaiser Wilhelm Land and from off the south of South America (Metcalf, 1918; Thompson, 1948). Sewell (1926) is quoted by Thompson as saying the genus *Ihlea* has probably adopted a cold-water habitat and that its surface distribution is limited, at any rate largely, to circumpolar regions.

Thompson (1948) in discussing the Australian records of *Ihlea magalhanica* concludes that "it is one of the salp species which has a low tolerance of warm-water conditions" and, "this species will therefore probably be useful as an indicator of any northern extension of the colder type of water conditions which may from time to time occur." The temperatures in the region of its occurrences ranged between 11.6° and 22.25°C., the lower limit being relatively cool, for Australian conditions. He regards it as limited almost entirely to the upper 50 m. of water and states that maximum numbers occurred between October and February.

Twenty-five Lachlan samples yielded 1,192 specimens. Their distribution shows fairly conclusively that *I. magalhanica* is a warm-water rather than a cold-water species, at least about New Zealand. Its occurrences were in the warmest water (Figs. 18*a*, *b*; 19*d*); these included Station 326 outside of the immediate vicinity of

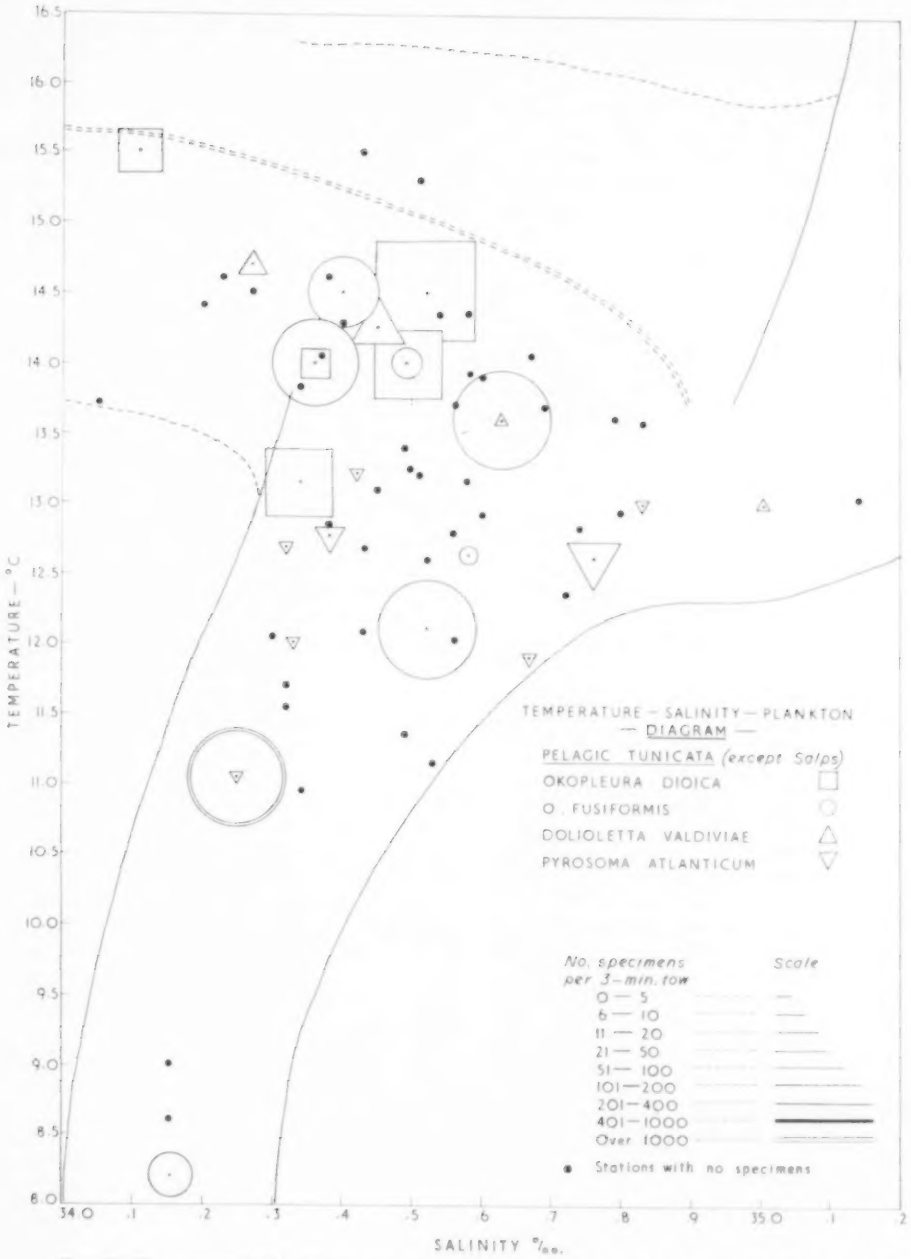


FIG. 22. Temperature-Salinity-Plankton diagram showing occurrences of species of pelagic tunicates other than salps.

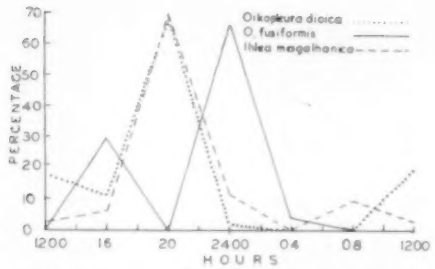


FIG. 23. Diurnal variation of numbers of specimens (collected at the surface) of *Oikopleura dioica*, *O. fusiformis*, and *Ihlea magalhanica*, as shown when the average catch per four-hour period is expressed as a percentage of the totalled average catches.

Foveaux Strait in water of subtropical origin (where it occurred with *Thalia democratica*). Again, when occurrences are plotted against salinity and temperature (Fig. 21) a distinct preference is demonstrated for the warmest water, which Bary (1959*a*) regards as being influenced by water of subtropical origin. The temperatures given by Thompson (11.6° to 22.25° C.) are inclusive of the range for subtropical water, given by Deacon (1937). The evidence from the present material, and possibly that from Thompson also, suggests the species may have subtropical, rather than cold-water origins.

DIURNAL MIGRATION

As the collections being considered are from the surface waters, diurnal migration can only be inferred from the variation of numbers between day and night samples. *Oikopleura dioica*, *O. fusiformis*, and *Ihlea magalhanica* occur spasmodically, but if the average four-hour catch is plotted as a percentage of the totalled average catches (Fig. 23) some smoothing of their occurrences is introduced. It is then found that *O. dioica* and *I. magalhanica* increase to a high percentage in the early evening (at 1800 to 1900 hours in untreated data). *Ihlea magalhanica* is present otherwise in comparatively small numbers, while *O. dioica* tends to occur throughout the day. *Oikopleura fusiformis* was present in markedly high numbers at 2400 hours (2400 to 0100 hours in untreated data), and again, but in lower numbers, at 1600 hours (two peaks, one at 1500 and the other at 1700 hours, in untreated data). Thus there are indications that numbers increase towards evening, or during darkness. However, the shoaling of salps, and, to judge from their irregular appearances, a tendency to swarming among appendicularians, makes any other than these tentative conclusions unwarranted.

In connection with vertical migration among tunicates, Russell and Colman (1935) showed that in the area of the Great Barrier Reef appendicularians migrated to near the surface between 2100 and 2325 hours and sank during daylight, when they concentrated at about 10 m. Mackintosh (1934: 94) and Hardy (1936: 521) illustrate and discuss vertical migration among salps, including the effects of swarming. It is shown that increases occur at or near the surface around midnight if due allowance is made for the existence of the swarms. It is probable, therefore, that the increases illustrated in Figure 23 to some extent are the result of vertical migration, although further sampling will almost certainly refine the patterns obtained.

Variation of numbers at the surface is shown by *Dolioletta valdiviae* for Stations 74 to 85 (at these stations the net was streamed in a tidal stream whilst the ship was at anchor, see Bary, 1956). The combined gonozooids, phorozooids, and old nurses (Fig. 24) increase in numbers to a peak at 2200 hours, decline to zero at 2400 hours, and increase to a second peak at 0200 hours. Data concerning doliolids for Station 83

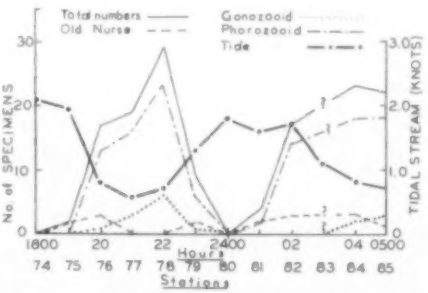


FIG. 24. Variation of numbers of the gonozooid, phorozooid, old nurse, and totalled specimens of *Dolioletta valdiviae*, during the course of one night when the ship was anchored and the net was streamed in a tidal stream.

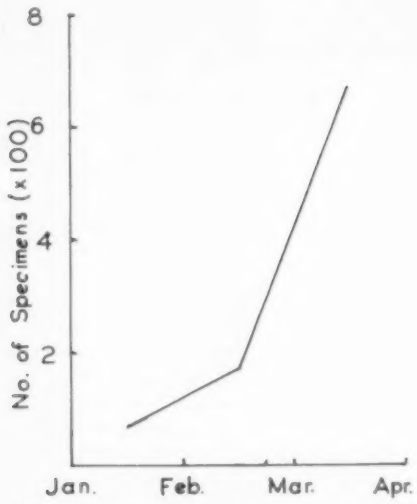


FIG. 25. Variation in average number of specimens per haul of all species of tunicate for January, February, and March, 1951.

are lost, and curves have been continued to Station 84 (0400 hours), but are queried. High numbers were still present at 0400 and 0500 hours, when sampling was discontinued. Individually, phorozooids, gonozooids, and old nurses show somewhat similar patterns to the average and to each other. More data are necessary to verify that the results illustrated are, in fact, the result of diurnal migration. Each of the peaks of numbers shows a degree of correlation with low tidal velocities which may not be coincidental, although reasons for this are not clear.

TUNICATES AS INDICATOR SPECIES

Results accruing from Lachlan samples on the use of salps as practical indicator species are meagre. Distinct preferences are apparent when occurrences are plotted against salinity and temperature (Figs. 21, 22) and some of these probably would persist, even with more samples, e.g., as for *Iblea magalhanica* and *Iasis zonaria*. Most of the species of tunicates cannot be regarded as practical indicators in that they occur so spasmodically. In conjunction with other 'Indicator Species,' as demonstrated in T-S-P diagrams, some of them provide useful additional evidence of the presence of particular waters, e.g., *Thalia democratica* and *Iblea magalhanica*.

Distinctions between the faunas on either side of the subtropical convergence are not evident from the distribution of the tunicates.

On the other hand, distinct "coastal" and "oceanic" faunas appear to exist, the former consisting of *Iblea magalhanica* and *Oikopleura dioica*, and the latter of most of the remaining species. How such relatively passive planktonts are able to maintain these distributional distinctions, especially in the strong tidal currents existing about the southern coasts of New Zealand, is a problem. Boden (1952), Hart (1953), and Bary (1959*a*) suggest that differential circulation between near and offshore waters may exert considerable influences.

SEASONAL DISTRIBUTION

The very spasmodic appearance of the majority of species of tunicates makes it difficult to indicate the nature of their seasonal distribution for January, February, and March, 1951. Average numbers taken per tow, of all species, do show a sharp increase to March (Fig. 25). This average condition, however, masks a number of species irregularities. For example, *Pyrosoma atlanticum* appeared late in January (one specimen), and increased in numbers steadily to March; *Salpa fusiformis* f. *aspera* occurred in early January, again at the end of February, and again at the middle and end of March; *Iblea magalhanica* occurred in January, and again in March, and so on. Some of the increases in the numbers of specimens are almost certainly seasonal, but irregularities such as result from the sampling of swarms tend to produce a misleading picture for most species. To be reliable, data would need to be available from several seasons. Similar irregularities in catches, and their effects on curves of their distribution, are illustrated for several salps from the Barrier Reef by Russell and Colman (1935).

SUMMARY

Notes are given on the systematics of *Oikopleura dioica* and *O. fusiformis*, *Doliolum* (*Dolioletta*) *valdiviae*, *Pyrosoma atlanticum* and *P. spinosum*, and of the salps *Iasis zonaria*, *Thalia democratica*, *Pegea confoederata*, *Salpa fusiformis* f. *aspera*, and *Iblea magalhanica*. The

"old nurse" stage of *Doliolella valdiviae* is believed to have been collected and is described and discussed in relation to the "old nurse" of *D. gegenbauri*. Occurrences in relation to temperatures and salinities, and the distribution of species in New Zealand waters, are discussed.

REFERENCES

AIDA, T. 1907. Appendicularia of Japanese waters. J. Coll. Sci. Tokyo 23(5): 1–25.

BARY, B. M. 1953. Sea-water discoloration by living organisms. N. Z. J. Sci. Tech., Sec. B., 34(5): 393–407.

——— 1956. Notes on ecology, systematics and development of some Mysidacea and Euphausiacea (Crustacea) from New Zealand. Pacif. Sci. 10(4): 431–467.

——— 1959*a*. Species of zooplankton as a means of identifying different surface waters and demonstrating their movements and mixing. Pacif. Sci. 13(1): 14–54.

——— 1959*b*. Ecology and distribution of some pelagic Hyperiidea (Crustacea, Amphipoda) from New Zealand waters. Pacif. Sci. 13(4): 317–334.

BERRILL, N. J. 1950. The Tunicata. Ray Soc. Publ. Pp. 1–354. Bernard Quaritch Ltd., London, England.

BODEN, B. P. 1952. Natural conservation of insular plankton. Nature, Lond. 169(4304): 697–699.

DAKIN, W. J., and A. N. COLEFAX. 1940. The plankton of Australian coastal waters off New South Wales, Part I. Monog. Dep. Zool. Univ. Sydney I, pt. I: 5–215.

DEACON, G. E. R. 1937. The hydrology of the Southern Ocean. 'Discovery' Rep. 15: 1–124.

ESSENBERG, C. E. 1926*a*. Copelata from the San Diego region. Publ. Univ. Calif. Zool. 28(22): 399–521.

——— 1926*b*. Observations on the gradual disintegration and death of Copelata. Publ. Univ. Calif. Zool. 28(23): 523–525.

FRASER, J. H. 1947. Thaliacea I and II. IN Fiches d'Ident. du Zooplancton. Sheets 9 and 10. Cons. Int. Explor. Mer.

GARSTANG, W. 1933. Report on the Tunicata, Part I. Doliolida. Sci. Rep. Brit. Antarc. (Terra Nova) Exped. [1910] 4(6): 195–251.

GARSTANG, W., and E. GEORGESON. 1935. Report on the Tunicata, Part II. Copelata. Sci. Rep. Brit. Antarc. (Terra Nova) Exped. [1910] 4(8): 263–282.

HARDY, A. C. 1936. Observations on the uneven distribution of oceanic plankton. 'Discovery' Rep. 11: 511–538.

HART, T. J. 1953. Plankton of the Benquela Current. Nature, Lond. 171(4354): 631–634.

HERDMAN, W. A. 1888. Report on the Tunicata collected during the voyage of the H.M.S. "Challenger" during the years 1873–76. Part 3. 'Challenger' Rep. 27.

MACKINTOSH, N. A. 1934. Distribution of the macroplankton in the Atlantic Sector of the Antarctic. 'Discovery' Rep. 9: 65–160.

METCALF, M. M. 1918. The Salpidae: a taxonomic study. Bull. U.S. Nat. Mus. 100. Vol. 2, pt. 2.

METCALF, M. M., and N. S. HOPKINS. 1919. *Pyrosoma*, a taxonomic study based upon the collections of the United States Bureau of Fisheries and the United States National Museum. Bull. U.S. Nat. Mus. 100, 2(3): 195–275.

RITTER, W. E. 1905. The pelagic Tunicata of the San Diego region, excepting the Larvaceae. Publ. Univ. Calif. Zool. 2(3).

RITTER, W. E., and E. S. BYXBEE. 1905. The pelagic Tunicata. Mem. Mus. Comp. Zool. Harv. 26(5): 195–214. Rep. Sci. Res. Explor. Trop. Pacific 'Albatross,' No. 8.

RUSSELL, F. S., and J. S. COLMAN. 1935. The zooplankton, IV. The occurrence and seasonal distribution of the Tunicata, Mollusca and Coelenterata (Siphonophora). Sci. Rep. Gr. Barrier Reef Exped. [1928–29] 2(7): 207–210.

SEWELL, R. B. S. 1953. The pelagic Tunicata. Sci. Rep. Murray Exped. [1933–34] 10(1): 1–90.

THOMPSON, H. 1942. Pelagic tunicates in the plankton of southeastern Australian waters and their place in oceanographic studies. Bull. Sci. Ind. Res. Org., Melbourne 153: 1–56.

——— 1948. Pelagic tunicates of Australia. Handb. Sci. Ind. Res. Org., Melbourne.

TOKIOKA, T. 1940. Some additional notes on the Japanese Appendicularia fauna. Rec. Oceanogr. Wks. Jap. 11(1): 1–26.

Early Larval Development of *Polydora nuchalis* Woodwick, a Spionid Polychaete

KEITH H. WOODWICK[1]

THE MOST RECENT detailed work treating the larval development of *Polydora*, that of Hannerz (1956), appeared a little more than one century after Oersted (1843) described for the first time a larval stage in *Polydora ciliata* (Johnston), Wilson 1928. Related papers presented during the interval included those of Claparède (1863), Agassiz (1867), Jacobi (1883), Whitelegge (1890), Andrews (1891), Mesnil (1896), Leschke (1903), Söderström (1920), Wilson (1928), Rioja (1939 and 1941), Hartman (1941), Thorson (1946 and 1950), Smidt (1952), and Casanova (1952). Each of these added information valuable to the understanding of polydorid development, but, as yet, in only a few forms is the early development known in detail.

The purpose of this paper is to make known the early developmental stages of a recently described polydorid, *Polydora nuchalis* Woodwick (1953).

METHOD

The developmental stages of *P. nuchalis* were cultured either in petri dishes containing sea water and sand from the original collecting area or in aquaria of circulating aerated sea water after the method of Reish (1953). Favorable results were obtained with both of these methods.

Observations were made of encased larvae (in egg capsules) as well as free-swimming individuals. The study of living material on depression slides provided specimens unaltered by fixation or cover glass pressure. Drawings of living forms were made employing the technique of Wilson (1928) and were inked following a comparative study of several other larvae of the same age group.

The drawings do not constitute a continuous developmental series from one individual but are a synthesis of a series of observations of individuals from a number of egg cases. The ages assigned the various stages are not absolute but, because they are based on multiple observations, are considered to be reasonable.

COMPOSITE POLYDORA LIFE HISTORY

An understanding of the larval development of polydorids is expedited by an understanding of the relationship of these larval stages to the remainder of the life history. A composite life history of members of the genus is presented below; *P. nuchalis* follows this scheme in most stages but does show individual differences.

A composite life history as extracted from the literature may be summarized in the following manner. An adult male and female copulate. Fertilization is internal. The female spawns the fertilized eggs through the nephridial canal and into transparent capsules. The capsules, formed in the manner described by Söderström (1920), are attached to the inner wall of the female's tube or burrow. Cleavage of the fertilized egg is complete but unequal. Further development of larvae within the egg capsule follows one of two types: (1) In *Polydora ciliata* (Wilson, 1928) and certain other species each egg in the capsule gives rise to a larva. The larvae leave the capsule at the 3-segment (setigerous segment) stage as planktotrophic forms to begin a long planktonic period (four to six weeks) prior to settling and metamorphosis. (2) In *Polydora hoplura* (Wilson, 1928) which represents the other type, each egg in the capsule does not give rise to a larva. The few which do develop, feed on the undeveloped eggs (nurse eggs). The larvae begin feeding at about the 3-segment stage but do not leave the capsule until about the 12-segment stage. The hatched larvae pass through a very short planktonic stage, if any, before settling and metamorphosis.

The latter type of development is found in

[1] Department of Biology, Fresno State College, Fresno, California. Manuscript received October 13, 1958.

P. nuchalis. Larvae leave the egg capsules after having fed on nurse eggs until the 9- to 12-segment stage (Plate I, Fig. 1). Further studies, to be reported in another paper, suggest that male and female do not copulate as such; a reciprocal transfer of sperm involving two protandric males occurs. The stored sperm fertilize the eggs which develop in the later female stage of protandry in each individual. Protandry and also neoteny have been reported for *Polydora hermaphroditica* Hannerz (1956).

Polydora nuchalis does, however, follow rather closely the composite life history in the remaining development. The larval stages described below are not unlike those figured for other species of *Polydora*.

EARLY DEVELOPMENTAL STAGES OF *Polydora nuchalis*

Egg. (Plate I, Fig. 2.) The eggs are round and about 120 μ in diameter. They include a central mass of light pink yolk granules and a very narrow peripheral region which is transparent. The yolk granules described here appear in the gut of all the developing stages up to at least 10 segments and are useful in determining the developmental boundaries of the gut in all these stages.

Cleavage of the egg is total but unequal as has been reported for other polydorids.

Early Larva, 18 Hours. (Plate I, Fig. 3.) The larva, 180 μ long, is transparent anteriorly, the yolk granules being concentrated in the posterior half. The primordia of the peristomium and prostomium are set off by ridges. This stage has an unusual anteroventral prolongation of the larval body. The prolongation was noted in more than one series of larvae but no suggestion can be made here as to its significance. It may be abnormal, but its repeated appearance and the fact that larvae of this kind continued to develop in a normal fashion later have led to its inclusion to allow comparison with possible future investigations on this and other species. The prototroch is located on the ventrolateral surface near the junction of the main body of the larva and the anteroventral prolongation. The telotroch has appeared also but is lacking from a wide dorsal portion.

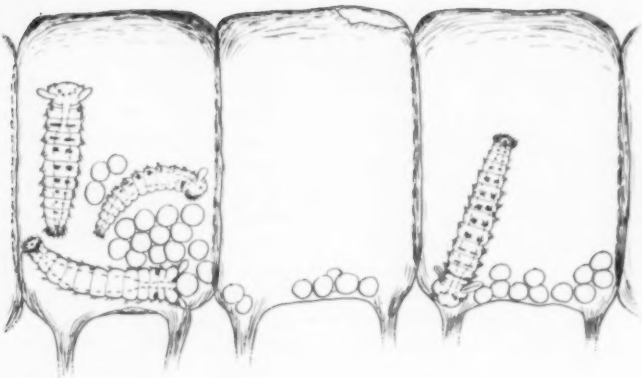
Early Larva, 36 Hours. (Plate I, Fig. 4.) The anteroventral prolongation is no longer present in this stage and the larva measures only 120 μ in length. The anterior part of the larva remains transparent; the posterior part is filled with yolk granules. The prototroch, not apparent in this figure, is limited mainly to the ventral region. The formation of the vestibule and the anterior portion of the gut has been initiated.

Late Presegment Larva, 72 Hours. (Plate I, Fig. 5.) The larva has elongated and does not so closely resemble the egg as did the two preceding larval stages. The larva is about 200 μ long, nearly double the length of the preceding stage; however, it has no true segments as yet. The anterior and the posterior body regions are transparent with the yolk present in the central region serving as an excellent indicator of the intestinal portion of the digestive tract. The transparency of the posterior region is a result of the development of the pygidium. The telotroch is well developed and prominent. The prototroch is present laterally, just posterior to the two eyes. The lateral eyes are the first pigment areas to be formed. Differentiation of the head and body has begun.

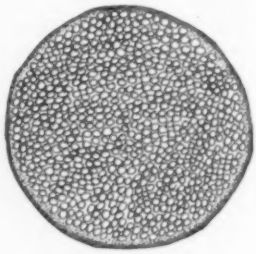
Early Two-Segment Larva, Five Days. This larva, 0.26 mm. long, has two complete segments and the beginning of a third pair of setal sacs. Two pairs of eyes are now present in the transparent anterior region. The palpi are beginning to bud laterally just posterior to the eyes. The development of the vestibule has continued; the mouth proper is visible. The posterior gut has begun to invaginate but has not joined the central concentration of yolk granules. The pygidium is set off from the rest of the body by a depression in the body surface which contains the base of the cilia of the telotroch. The first pair of dorsal melanophores is located on the primordia of the third segment.

Three-Segment Larva, Six Days. (Plate II, Fig. 1.) The larva, 0.30 mm. long, has three well-developed segments. It is transparent except for segments two and three in which the gut contains yolk granules.

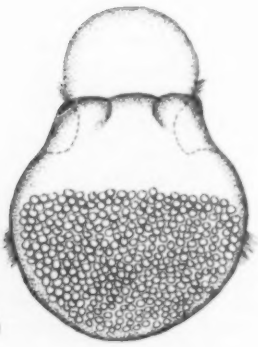
The palpi have thickened but have not elongated. The protroch and telotroch are as described for the previous stage. The pygidium is cone-shaped and papillated; its appearance is



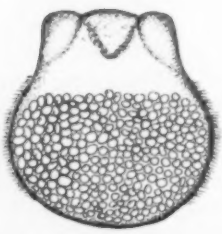
1



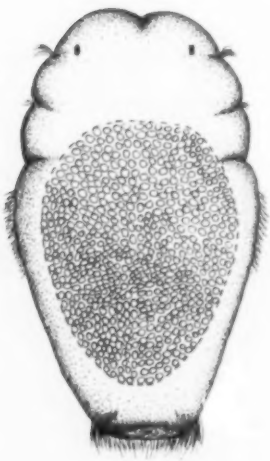
2



3



4



5

PLATE I. Fig. 1. Egg capsules and larvae. Fig. 2. Egg, 0.12 mm. Fig. 3. Early larva (18 hours), 0.18 mm. Fig. 4. Early larva (36 hours), 0.12 mm. Fig. 5. Late pre-setiger larva (72 hours), 0.20 mm.

similar to that described by Hartman (1941) for an unknown spionid larva. The melanophores on the third segment have elongated laterally and another pair has formed on the developing fourth segment.

This 3-segment stage has three pairs of eyes. Later, the two pairs which are anterolateral fuse on each side producing a single anterolateral pair. Four eyes, the fused pair and the median pair, are retained throughout life.

The vestibule has enlarged but has not as yet opened to the granular intestinal portion of the gut. The ciliated posterior invagination of the gut nearly reaches the third segment and after a few additional hours of development its cavity becomes joined to that of the granular intestinal portion. This junction, along with completion of the vestibular portion, will produce a functional digestive tract. In larvae having a long pelagic life, completion of the gut development and hatching are concurrent and larvae are able to feed upon leaving the egg cases; this is usually at the 3-segment stage. *Polydora nuchalis* does not hatch at the 3-segment stage but does begin to feed on the nurse eggs. The stage at which gut development is completed, however, is not so critical in a species of *Polydora* having nurse eggs.

Five-Segment Larva, One Week. This larva is about 0.50 mm. in length. It has five setigerous segments and at least three more segments which are forming. The entire animal is transparent except for a few yolk granules present in the gut. Most larvae of this size have a complete digestive tract including a vestibule, esophagus, intestine, rectum, and anus. The vestibule, esophagus, and rectum are greatly ciliated.

The palpi have elongated but the prototroch, telotroch, and pygidium are as described for the preceding stage. Two pairs of eyes are present in the normal adult position with the lateral pair anterior to the median pair.

The dorsal paired melanophores are elongated on segment three and smaller pairs are present on segments four and five. There is also a single pygidial melanophore.

Ten-Segment Larva, About Two Weeks. (Plate II, Fig. 2.) This larva is 0.65 mm. in length and has 10 segments formed with the eleventh segment nearly complete in its development. The larva illustrated does not contain nurse egg material although it is often found in the gut of larvae of this and later stages. The large ventral vestibule passes food into the long, ciliated esophagus from which it moves to the intestine beginning at segment four. The anus opens in the central portion of the pygidium which has become flattened. The dorsal notch characteristic of the adult pygidium is not present.

The eyes are as in the previous stage, but the palpi are more elongate. Notopodial lobes are present in all the segments. Those of the first segment are located more dorsally than the others and are, thus, nearer the midline. The neuropodial lobes of the first segment are on the same lateral plane as the notopodial lobes of the other segments. This condition prevails in the adult. Branchiae are not present. Melanophores are present on segments three and four as paired dorsal elongations and on the succeeding six segments as paired dots which diminish in size on the more posterior segments. Segments two, seven, and eight have lateral pigment spots. The pygidial melanophore is present. A single stout spine is situated in the notopodium on each side of the modified fifth segment.

Fifteen-Segment Larva, Three Weeks. (Plate III.) This form represents the settling stage of *P. nuchalis*. It is similar in appearance to the adult, but will be discussed here as the final larval stage. It is 0.90 mm. in length and has 15 fully developed segments and a sixteenth partly developed.

The anterior end is adultlike with the peristomium and prostomium greatly developed in comparison with previously described stages. The prostomium is bilobed anteriorly. Two pairs of eyes are located on the prostomium. The nuchal tentacle, one of the diagnostic characters for *P. nuchalis*, is now present on the posterior part of the prostomium. The elongate palpi which arise from the peristomium extend as far as the modified fifth segment. Each of the palpi has a median ciliated groove used in the feeding process. The central body portion, like the anterior portion, resembles that of the adult but the pygidial portion does not. The pygidium is

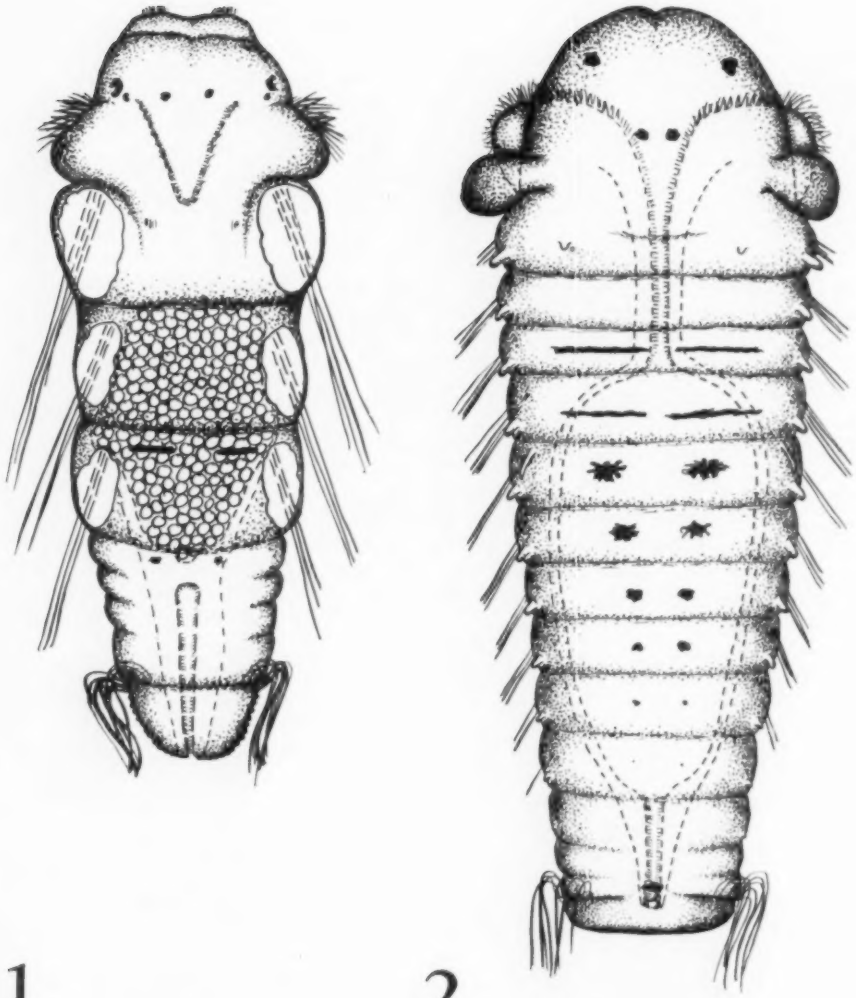


PLATE II. Fig. 1. 3-setiger larva (six days), 0.30 mm. Fig. 2. 10-setiger larva (two weeks), 0.65 mm.

broad and flangelike but certain changes in ciliary tracts and pigmentation associated with metamorphosis, to be mentioned below, have yet to occur.

The vestibule leads into a long esophagus which joins the intestine at the anterior end of the sixth segment and a long rectum extends from about segment ten to the posterior end of the body. Cilia are present in the vestibule, esophagus, and rectum but are not indicated in the figure.

The prototroch and telotroch are ordinarily lost shortly after settling occurs as one of the changes in the metamorphosis from larva to adult. Gastrotrochs, not mentioned previously, are found on segments three, five, seven, ten, thirteen, and fifteen. These ventral, ciliary tracts first appear on segment three in early stages of development and on succeeding segments (of the numbers mentioned above) as development continues. They are important locomotor organs in the short free-swimming period of *P. nuchalis* and the longer free-swimming periods of forms which hatch at the 3-segment stage.

The conspicuous dorsal melanophores are present only on segments twelve and thirteen and will be lost from these in succeeding stages. The pygidial melanophore and lateral pigment spots present on segment eight and the right side of segment nine are lost in metamorphosis. While in the egg capsule and until shortly after hatching, the larvae are positively phototropic; but at the time of settling and metamorphosis the melanophores and pigment spots are lost and the larvae become negatively phototropic. This suggests rather strongly a functional relationship between the phototropic change and loss of pigmentation.

Two heavy spines are present in each notopodium of the modified fifth segment, the largest of the body segments. Neuropodial hooded hooks appear first in segment seven. Branchiae also appear first on segment seven and in the 15-segment stage are partly formed on segment eight, as well.

The larvae ordinarily hatch at the 12-segment stage, but they may leave the egg case at the 9-segment stage. The larvae settle, metamor-

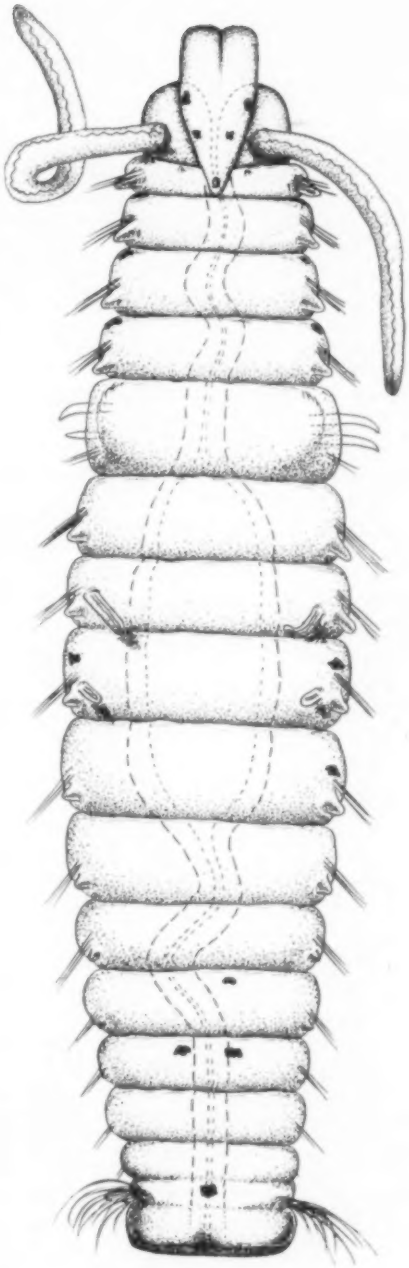


PLATE III. 15-setiger larva (three weeks), 0.90 mm.

phose, and build tubes during the 13- to 17-segment stage.

The adult characteristics are considered in Woodwick (1953).

ACKNOWLEDGMENTS

The writer is indebted to the Biology Department of the University of Southern California and to the Allan Hancock Foundation for research space and equipment and to Dr. Olga Hartman, Dr. John L. Mohr, and Dr. Donald J. Reish for invaluable assistance.

REFERENCES

AGASSIZ, A. 1867. On the young stages of a few annelids. Ann. Mag. Nat. Hist. Ser. 3, 19: 203–218, 242–257.

ANDREWS, E. A. 1891. A commensal annelid. Amer. Nat. 25: 25–35.

CASANOVA, L. 1952. Sur le développement de *Polydora antennata* (Claparède). Arch. Zool. Exp. Gén. 89(3): 95–101.

CLAPARÈDE, E. 1863. Beobachtungen über Anatomie und Entwicklungsgeschichte wirbelloser Thiere an der Küste von Normandie angestellt. vii + 120 pp. Leipzig.

HANNERZ, L. 1956. Larval development of the polychaete families Spionidae Sars, Disomidae Mesnil, and Poecilochaetidae n. fam. in the Gullmar Fjord (Sweden). Zool. Bidr. Uppsala. 31: 1–204.

HARTMAN, O. 1941. Some contributions to the biology and life history of Spionidae from California. Allan Hancock Pacif. Exped. 7: 289–324.

JACOBI, R. 1883. Anatomisch-histologische Untersuchung der Polydoren der Kieler Bucht. Inaugural Dissertation. Kiel. (Weissenfels, Leopold Kell). 37 pp.

LESCHKE, M. 1903. Beiträge zur Kenntnis der pelagischen Polychaetenlarven der Kieler Föhrde. Wiss. Meeresuntersuch. 7: 113–134.

MESNIL, F. 1896. Études de morphologie externe chez les Annélides. Les Spionidiens des côtes de la Manche. Bull. Sci. Fr. Belg. 29: 110–287.

GERSTED, A. S. 1843. Annulatorum danicorum conspectus, Fasc. 1. Maricolae. Pp. 1–52.

REISH, D. J. 1953. Description of a new technique for rearing polychaetous annelids to sexual maturity. Science 118 (3065): 363–364.

RIOJA, E. 1939. Estudios anelidologicos I. Observaciones acerca de varias formas larvarias y postlarvarias pelagicas de Spionidae, precedentes de Acapulco, con descripcion de una especie nueva del genero *Polydora*. Ann. Inst. Biol. Univ. Mex. 10: 297–311.

——— 1941. Estudios anelidologicos III. Datos para el conocimiento de la fauna de Poliquetos de las costas del Pacifico de Mexico. Ann. Inst. Biol. Univ. Mex. 12: 669–746.

SMIDT, E. L. B. 1952. Animal production in the Danish Waddensea. Medd. Komm. Havundersøg. Kbh. 11(6): 1–151.

SÖDERSTRÖM, A. 1920. Studien über die Polychaetenfamilie Spionidae. Dissertation. Uppsala. (Almquist and Wicksells.) 286 pp.

THORSON, G. 1946. Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the Sound (Øresund). Medd. Komm. Havundersøg. Kbh. 4(1): 1–523.

——— 1950. Reproductive and larval ecology of marine bottom invertebrates. Biol. Rev. 25: 1–45.

WHITELEGGE, T. 1890. Report on the worm disease affecting the oysters on the coast of New South Wales. Rec. Aust. Mus. 1: 41–53.

WILSON, D. P. 1928. The larvae of *Polydora ciliata* Johnston and *Polydora hoplura* Claparède. J. Mar. Biol. Ass. U.K. 15: 567–603.

WOODWICK, K. H. 1953. *Polydora nuchalis*, a new species of polychaetous annelid from California. J. Wash. Acad. Sci. 43(11): 381–383.

Contributions to the Knowledge of the Alpheid Shrimp of the Pacific Ocean
Part V. The Indo-Pacific Members of the Genus *Athanas*[1]

ALBERT H. BANNER and DORA MAY BANNER[2]

THE FOUR PAPERS previously published in this series have dealt with Alpheid shrimp by geographical areas. For this paper, because a major revision of the genus is needed and the shrimps upon which the revision is based come from many different regions of the Pacific, it was considered better to deal with the genus as a whole. Some of the specimens here discussed have been reported in the four previous studies. Those specimens which have not been listed in the previous studies come from three major sources: specimens collected on the Coral Atoll Investigations made by the Pacific Science Board; specimens collected by the senior author travelling in the central Pacific under a grant from Bernice P. Bishop Museum, Honolulu; and specimens collected at Eniwetok and other Marshall Islands, by the senior author and by others under the sponsorship of the Atomic Energy Commission. In this paper, details on collections are not given; these can be found in previous or future papers.

The present study has been supported by National Science Foundation Grant NSF-G-1754. The authors wish to acknowledge their indebtedness to L. B. Holthuis for the use of the bibliography of species of higher crustacea prepared by him; without this help the list of references would have been almost impossible to prepare, especially in Honolulu where the libraries lack many of the older works.

Since the genus *Athanas* was first described by Leach in 1814, some 43 specific and subspecific names have been applied to the members of this genus, only 7 of which are not known from the Pacific and Indian oceans. The shrimp in this genus are small and inconspicuous; as a result most of the previous workers had only a few specimens, often broken, upon which to base their description; further, of the Indo-Pacific species, at least 18 have not been reported since their original capture.

The Indo-Pacific genus *Arete*, long accepted as being closely related to *Athanas*, has a somewhat similar history. Since the genus was erected by Stimpson in 1861 for the species *A. dorsalis*, 11 names have been applied to species within the genus, and 4 of these names have been based upon 3 specimens or less.

The specimens available for this study were in some cases collected in large numbers. As will be discussed below, almost all of the species which are so represented show marked variation with size and sex in the form of the large chelae, and several species appear to vary considerably in the form of the rostrum and teeth of the carapace about the eyes. As these are the chief characteristics that have been used in the separation of many of the species, a revision of the two genera is necessary. Unfortunately, the present collections do not contain representatives of enough species to permit a monographic revision, so the purpose of this paper will be to merely initiate such a revision, which other workers from other parts of the Indo-Pacific may elaborate upon and finish.

ANNOTATED BIBLIOGRAPHY OF THE SPECIES OF *Athanas* AND *Arete*

In the following listing, all species placed in these genera have been listed with reference to the original description and all subsequent Indo-Pacific records. The number of specimens upon which the original description or subsequent redescription were based has been given, wherever possible, together with the localities where the specimens were collected. Most synonyms are indicated in this listing; in the synonymies later in the paper, reference is made back to this listing.

[1] Contribution No. 124, Hawaii Marine Laboratory. Manuscript received November 1, 1958.

[2] Department of Zoology and Entomology, University of Hawaii, Honolulu, Hawaii.

Athanas nitescens (Leach) (described as *Palaemon nitescens*), 1814. Edinb. Encyc. 7: 401. [Not Indo-Pacific.]

Athanas edwardsii Audouin, 1827. Explication sommaire des planches de Crustacés de l'Égypte et de la Syrie, ed. 2, vol. 22, pp. 249–290. Atlas Hist. Nat. vol. 2, Crustacea, pls. 1–13. [Citation taken directly from the bibliography of Holthius. For discussion of date of publication, see Sherborn, C. D., 1897. Proc. Zool. Soc. Lond., pp. 285–288.] [Now *Alpheus edwardsii*.]

Athanas monoceros (Heller) (described as *Alpheus monoceros*), 1861. S.B. Akad. Wiss. Wien 44: 274; Red Sea. [Coutière, 1899: 61, 62, makes this a variety of *A. dimorphus* Ortmann 1894, a procedure contrary to the rules of zoological nomenclature.]

Athanas mascarenicus Richters, 1880. Beitr. Meeresfauna der Insel Mauritius und der Seychellen, Decapoda, p. 164; Mauritius or Seychelles. [Coutière (1896: 381) states that Richters' specimen is too incompletely described or figured; in 1899: 33, he states this is a synonym of *Arete dorsalis* Stimpson; in 1905: 868, he stated he could not identify it with certainty with any known species.]

Athanas alpheoides Czerniawsky, 1884. Obshchestvo Ispuitateleĭ Prīroduc prī Imperatorskom Khar'kovskom Universītetye (Société des Naturalistes à l'Université Impériale de Kharkow) 13: 26. [Not Indo-Pacific. Coutière (1899: 37) states this is a juvenile.]

Athanas transitans Czerniawsky, 1884. Trans. Soc. Univ. Kharkov 13: 25. [Not Indo-Pacific.]

Athanas transitans longispina Czerniawsky, 1884. Trans. Soc. Univ. Kharkov 13: 25. [Not Indo-Pacific.]

Athanas veloculus Spence Bate, 1888. Challenger Reps. 24: 529, pl. 96, fig. 1. [Not Indo-Pacific.]

Athanas dimorphus Ortmann, 1894. Denkschr. Med.-Naturw. Ges. Jena 8: 12, taf. 1, fig. 1; 3 specimens from Dar es Salaam, East Africa.

——— Coutière, 1897b. Bull. Mus. Hist. Nat., Paris 3(7): 301. [Here Coutière placed his species *A. dispar* in synonymy.]

——— Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 77, fig. 12; Red Sea, New Caledonia. [Drawing of large chela of female.]

——— Balss, 1915. Ergebn. Zool. 30: 21; 1 specimen from the Red Sea.

——— Tattersall, 1921. J. Linn. Soc. (Zool.) 34: 371, pl. 28, figs. 23, 24; 1 specimen from the Red Sea. [Partial redescription.]

——— Gurney, 1924. Zool. Res. Cambridge Exp. Suez Canal, p. 260. [Larval development.]

——— Balss, 1927. Trans. Zool. Soc. Lond. 22: 222; 1 female from Dar es Salaam, East Africa. [Record of capture.]

——— Gurney, 1927. Trans. Zool. Soc. Lond. 22: 260, fig. 63. [Larval development.]

——— Kollmann, 1937. Ann. Fac. Sci. Marseille II, 10: 145, figs. 16–17. [Journal unavailable.]

Athanas nitescens veloculus Coutière, 1896. Bull. Mus. Hist. Nat., Paris 2: 380. [Not Indo-Pacific.]

Athanas leptocheles Coutière, 1896. Bull. Mus. Hist. Nat., Paris 2: 381; 1 specimen from the Red Sea. [Coutière (1897: 233) stated these were females of species renamed *A. dispar*.]

Athanas leptocheles monoceros Coutière, 1896. Bull. Mus. Hist. Nat., Paris 2: 381; 4 specimens from the Red Sea. [Coutière (1896: 381) considered *A. transitans longispina* a synonym of this species.]

Athanas solenomerus Coutière, 1896. Bull. Mus. Hist. Nat., Paris 2: 381; 1 specimen from the Red Sea. [Coutière (1897: 233) stated this was the male of the species he renamed *A. dispar*.]

Athanas dispar Coutière, 1897. Bull. Mus. Hist. Nat., Paris 3: 233; several specimens from Djibouti. [Coutière (1897: 301) stated this was a synonym of *A. dimorphus* Ortmann.]

Athanas dispar monoceros Coutière, 1897. Bull. Mus. Hist. Nat., Paris 3: 233 (in a footnote). [See *A. monoceros* above and *A. dimorphus monoceros* below.]

Athanas djiboutensis Coutière, 1897. Bull. Mus. Hist. Nat., Paris 3: 233; 2 specimens from Djibouti.

——— Coutière, 1899. Ann. Sci. Nat. VIII, 9: 62, fig. 4; p. 177, fig. 207. [Discussion of rostrum and chela.]

——— Coutière, 1903. Bull. Soc. Philom. Paris

IX, 5(2): 75; specimens from the Maldive and Laccadive Archipelagoes. [Characteristics and general distribution.]

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 856, fig. 129. [Same as the above.]

——— Nobili, 1906. Ann. Sci. Nat. IX, 4: 31; 1 specimen from the Red Sea. [Locality only.]

———. Nobili, 1907. Mem. R. Accad. Torino IIa, 57: 353; 2 specimens from the Tuamotus Archipelago. [Brief remarks.]

——— Tattersall, 1921. J. Linn. Soc. Zool. 34: 368, pl. 28, fig. 25; 9 specimens from the Sudanese Red Sea. [Description of specimens.]

——— de Man, 1922. Siboga Exped. 39a^4(5): 21; 1 mutilated specimen from Indonesia. [Description of specimen.]

——— Edmondson, 1925. Bull. Bishop Mus., Honolulu 27: 9; 1 specimen from Wake Island. [Record of capture.]

——— Gordon, 1935. Ann. Mag. Nat. Hist. X, 16: 629; Christmas Island, Indian Ocean. [Record of capture.]

——— Boone, 1935. Bull. Vanderbilt (Oceanog.) Mar. Mus. 6: 119, pl. 31; 2 specimens from Marquesas Islands. [Extensive description.]

——— Ramadan, 1936. Bull. Fac. Sci. Egypt. Univ. 6: 12; 4 specimens from Ghardaqa, Red Sea. [Remarks on chelae.]

——— Kollmann, 1937. Ann. Fac. Sci. Marseille II, 10: 145. [Reference not available.]

——— Gurney, 1938. Sci. Rep. Gr. Barrier Reef Exped. 6: 54, figs. 249–252. [Discussion of larval forms.]

——— Armstrong, 1941. Amer. Mus. Novit. (1137): 5; 1 female from Samoa. [Record of capture.]

——— Barnard, 1946. Ann. Mag. Nat. Hist. XI, 13: 388; specimens from Mozambique. [Locality only.]

——— Barnard, 1950. Ann. S. Afr. Mus. 38: 732–733, figs. 137 e–f; 1 specimen from Mozambique. [Brief description.]

——— Chace, 1955. Proc. U. S. Nat. Mus. 105(3349): 16; 11 specimens from the Marshall Islands. [Brief remarks.]

——— Banner, 1956. Pacif. Sci. 10(3): 322; 22 specimens from the Mariana Archipelago. [Brief discussion.]

——— Banner, 1957. Pacif. Sci. 11(2): 193; 2 specimens from the Marshall Islands. [Record of capture.]

Athanas sulcatipes Borradaile, 1898. Proc. Zool. Soc. Lond., p. 1011, pl. 65, fig. 9; 8 specimens from Funafuti. [Coutière (1905: 856) stated this was a synonym of *A. djiboutensis*.]

——— Anonymous, 1899. Mem. Aust. Mus. 3: 518; specimen from Funafuti. [Record of capture.]

Athanas ortmanni Rankin, 1898. Ann. N. Y. Acad. Sci. 12(11): 251, pl. 30, fig. 7. [Not Indo-Pacific. Now *Salmoneus ortmanni*.]

Athanas dimorphus monoceros (Heller) Coutière, 1899. Ann. Sci. Nat. VIII, Zool. 9: 61, 62. [Change of name, see *A. monoceros* Heller, 1861, above.]

Athanas naifaroensis Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 77, figs. 14–16; 1 specimen from the Maldive Archipelago.

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 859, fig. 131. [Same description as the above.]

——— Coutière, 1905. C. R. Acad. Sci., Paris 140: 737. [Review of species listed in Maldive and Laccadive Report.]

——— de Man, 1922. Siboga Exped. 39a^4(5): 16, pl. II; fig. 9; 1 specimen from Indonesia. [Description of specimen.]

——— Barnard, 1950. Ann. S. Afr. Mus. 38: 731, figs. 136 f–i; 1 specimen from Natal, South Africa. [Brief description.]

Athanas areteformis Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 79, figs. 17–18; 2 specimens from the Maldive Archipelago.

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 860, fig. 132. [Same description and figures as above.]

——— Coutière, 1905. C. R. Acad. Sci., Paris 140: 737. [Review of species listed in Maldive and Laccadive Report.]

——— Balss, 1915. Ergebn. Zool. 30: 21; specimen from the Red Sea. [Locality only.]

——— Chace, 1955. Proc. U. S. Nat. Mus. 105(3349): 21; 1 specimen from the Marshall Islands. [Locality only.]

Athanas minikoensis Coutière, 1903. Bull. Soc.

Philom. Paris IX, 5(2): 76, figs. 9–11; 1 specimen from Laccadive Archipelago, Indian Ocean.

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 858, fig. 130. [Same specimens and figures as the above.]

——— de Man, 1911. Siboga Exped. 39a¹(2): 149, pl. 2, figs. 5–5h; 2 specimens from Indonesia. [Description and figures.]

——— Ramadan, 1936. Bull. Fac. Sci. Egypt. Univ. 6: 13; 1 specimen from the Red Sea.

——— Barnard, 1946. Ann. Mag. Nat. Hist. XI, 13: 388; specimen from Natal, South Africa. [Locality only.]

——— Barnard, 1950. Ann. S. Afr. Mus. 38: 731, figs. 137 a–d; 1 specimen from Natal, South Africa. [Partial redescription.]

Athanas orientalis Pearson, 1905. Rep. Pearl Fish. Maanar 4(24): 88, pl. 2, fig. 10; 7 specimens from Ceylon.

Athanas haswelli Coutière, 1908. Bull. Soc. Philom. Paris IX, 11(5): 2; 1 female from south Adelaide coast, Australia.

——— Hale, 1927. Crustacea of South Australia. Vol. 1. P. 47. [Brief remarks, no additional specimens.]

Athanas granti Coutière, 1908. Bull. Soc. Philom. Paris IX, 11(5): 192; 5 specimens from south Adelaide coast, Australia.

——— Hale, 1927. Crustacea of South Australia. Vol. 1. P. 47. [Brief remarks, no additional specimens.]

Athanas sibogae de Man, 1910. Tijdschr. Ned. Dierk. Ver. II, 11(5): 314; 9 specimens from Indonesia.

——— de Man, 1911. Siboga Exped. 39a¹(2): 151, pl. 2, figs. 6–6h. [Redescription, same specimens as the above.]

Athanas tenuipes de Man, 1910. Tijdschr. Ned. Dierk. Ver. II, 11(5): 316; 1 specimen from Indonesia.

——— de Man, 1911. Siboga Exped. 39a¹(2): 157, pl. 3, figs. 8–8e. [Redescription, same specimen as the above.]

Athanas parvus de Man, 1910. Tijdschr. Ned. Dierk. Ver. II, 11(5): 315; 1 female from Indonesia.

——— de Man, 1911. Siboga Exped. 39a¹(2): 148, pl. 1, figs. 4–4d. [Redescription of same specimen.]

——— Tattersall, 1921. J. Linn. Soc. Lond. 34: 372; 3 specimens from the Red Sea. [Brief remarks.]

——— de Man, 1922. Siboga Rep. 39a¹(5): 16–18; 1 specimen from Indonesia. [Complete description.]

——— Kubo, 1940. Annot. Zool. Jap. 19(2): 99, figs. 1, 2; 1 specimen from Tanabe, Wakayama Prefecture. [Redescription.]

——— Miyadi, 1940. Annot. Zool. Jap. 19(2): 143. [Same specimen as reported by Kubo above.]

Athanas jedanensis de Man, 1910. Tijdschr. Ned. Dierk. Ver. II, 11(5): 313; 4 specimens from Indonesia.

——— de Man, 1911. Siboga Exped. 39a¹(2): 154–156, pl. 2, figs. 7–7f. [Redescription of same specimens.]

Athanas grimaldii Coutière, 1911. Bull. Inst. Océanogr. Monaco No. 197, figs. 1–6. [Not Indo-Pacific.]

Athanas polymorphus Kemp, 1915. Indian Mus., Mem. 5(3): 289, figs. 31, 32; 27 specimens from Chilka Lake, India.

Athanas sp. Stebbing, 1914. Ann. S. Afr. Mus. 15: 88; 1 specimen from Delagoa Bay, Indian Ocean.

Athanas stebbingi de Man, 1920. Zool. Meded. 5(3): 106; 1 specimen from Indonesia.

——— de Man, 1922. Siboga Exped. 39a¹(5): 18, pl. II, III, figs. 10–10f. [Redescription of same specimen.]

Athanas crosslandi Tattersall, 1921. J. Linn. Soc. Lond. 34: 372, pl. 27, figs. 13–17; 2 specimens from the Red Sea.

——— Ramadan, 1936. Bull. Fac. Sci. Egypt. Univ. 6: 12; specimen from the Red Sea. [Included in species listing.]

Athanas gracilis Boone, 1935. Bull. Vanderbilt Oceanogr. (Mar.) Mus. 6: 122–126, pl. 32; 1 specimen from Raiatea Island, Society Archipelago.

Athanas japonicus Kubo, 1936. J. Fish. Inst. Tokyo 31(2): 43, pl. 13; 3 specimens from Japan.

Athanas oshimai Yokoya, 1936. Jap. J. Zool. 7: 129, fig. 1; several specimens from Aburatubo, Japan.

Athanas erythraeus Ramadan, 1936. Bull. Fac. Sci. Egypt. Univ. 6: 13, pl. 1, fig. 1; 1 specimen from Ghardaqa, Red Sea.

Athanas esakii Kubo, 1940. J. Fish. Inst. Tokyo 34(1): 93, fig. 13; four specimens from Kusaie, Caroline Islands.

Athanas lamellifer Kubo, 1940. Annot. Zool. Jap. 19(2): 102–106; figs. 3–5; 4 specimens from Kominato, Japan.

Athanas kominatoensis Kubo, 1942. Zool. Mag. Tokyo 54: 82–84, fig. 2; 5 males from Kominato, Japan.

Athanas nouvelae Holthuis, 1951. Atlantide Rep. (2): 104–110, fig. 22. [Not Indo-Pacific.]

Athanas amazone Holthuis, 1951. Atlantide Rep. (2): 111, fig. 23. [Not Indo-Pacific.]

Athanas setoensis Kubo, 1951. J. Tokyo Coll. Fish. 38(2): 265, figs. 5, 6; 1 specimen from central Japan.

Athanas marshallensis Chace, 1955. Proc. U. S. Nat. Mus. 105(3349): 17–20, fig. 8; 22 specimens from the Marshall Islands.

——— Banner, 1957. Pacif. Sci. 11(2): 193, fig. 3 a–f; 1 specimen, Marshall Islands.

Athanas dubius Banner, 1956. Pacif. Sci. 10(3): 322–325, fig. 2 a–h; 10 specimens from Saipan, Mariana Archipelago.

Arete dorsalis Stimpson, 1861. Proc. Acad. Nat. Sci. Philad. 12: 32; found near Hong Kong. [Nec. *A. dorsalis* de Man (1888: 527), see *A. amboinensis*.]

——— Coutière, 1896. Bull. Mus. Hist. Nat., Paris 2: 385; 1 specimen from Samoa and 1 from the Indian Ocean. [Brief description.]

——— Coutière, 1897. Bull. Mus. Hist. Nat., Paris 3(6): 234; several specimens from Djibouti. [Remarks on ecology.]

——— Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 13, figs. 32–34. [States *A. dorsalis pacificus* Coutière is a synonym of *A. dorsalis*.]

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 866, figs. 136–137; 1 specimen from Goidu Atoll, Indian Ocean.

——— Chilton, 1910. Trans. Proc. N. Z. Inst. 43: 549; 3 specimens from Sunday Island, Kermadec Islands. [Description of specimens.]

——— de Man, 1911. Siboga Exped. 39a[1] (2): 167; 2 females from Indonesia. [Description of specimens.]

——— Gee, 1925. Lingnaam Agric. Rev. 3: 157; specimens from China. [Record of capture.]

——— Gordon, 1935. Ann. Mag. Nat. Hist. X, 16: 629; specimens from Christmas Island, Indian Ocean. [Record of capture.]

Arete monoceros Paulson, 1875. Crustacea Mer Rouge. [Paper not available; Coutière, 1899: 27, states this is *Athanas monoceros* (Heller).]

Arete mascarenicus (Richters), 1880. (As *Athanas mascarenicus*), Beitr. Meeresfauna der Insel Mauritius und der Seychellen, Decapoda, p. 164; Indian Ocean.

——— Coutière, 1897. Bull. Mus. Hist. Nat., Paris (7): 301. [Brief remarks.]

——— Coutière, 1899. Ann. Sci. Nat. VIII, Zool. 9: 33. [States this is a synonym of *A. dorsalis*.]

Arete borradailei Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 80; 1 specimen from the Maldive Archipelago.

——— Coutière, 1905. C. R. Acad. Sci., Paris 140: 737. [Listing of specimens in the Maldive Archipelago.]

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 861, fig. 133. [Same specimens as in 1903 above.]

Arete dorsalis pacificus Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 84, figs. 31–34; found in Hong Kong, has specimens from Samoa, New Caledonia, and Central America. [Coutière (1905: 866) states this is probably *A. dorsalis* Stimpson.]

——— Coutière, 1904. Bull. Mus. Hist. Nat., Paris 10(2): 58; several specimens from Marutea, Tuamotus. [Notes on commensalism; in 1905 Coutière names this form *A. maruteensis*.]

Arete dorsalis indicus Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 84; several specimens from Djibouti, one from the Maldive Archipelago. [Changed to *A. indicus* by Coutière (1905: 863), see below.]

Arete maruteensis Coutière, 1905. Bull. Mus. Hist. Nat., Paris 11(1): 18; 3 examples from

Marutea commensal with *Heterocentrotus mammillatus*.

——— Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 868. [Comparison with *A. dorsalis*.]

——— Nobili, 1907. Mem. R. Accad. Torino II, 57: 353; 5 specimens from Marutea, one from Fakarawa, one from Rikitea, French Oceania. [Remarks on commensalism.]

Arete indicus Coutière, 1905. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 863, figs. 134, 135; one specimen from Maldive Archipelago, numerous specimens from Djibouti and 1 from Central America. [See *A. dorsalis indicus* Coutière above.]

——— Nobili, 1906. Bull. Sci. Fr Belg. 20: 24; 1 specimen from the Persian Gulf. [Partial redescription.]

——— Balss, 1915. Ergebn. Zool. 30: 21; specimens from the Red Sea. [Locality only.]

——— Coutière, 1921. Trans. Linn. Soc. Lond. 17(4): 413; specimens from the Indian Ocean. [Locality only.]

Arete iphianassa de Man, 1910. Tijdschr. Ned. Dierk. Ver. II, 11(5): 312; 2 specimens from Indonesia.

——— de Man, 1911. Siboga Exped. 39a¹(2): 16, pls. 3, 4, figs. 11–11e. [Same as the above with figures.]

——— de Man, 1922. Siboga Exped. 39a¹(5): 22, pl. III, figs. 11–11f; 1 specimen from Indonesia. [Redescription.]

——— Banner, 1956. Pacif. Sci. 10(3): 324; 6 examples from the Marianas Islands. [Locality only.]

Arete maruteensis Coutière var. *salibabuensis* de Man, 1910. Tijdschr. Ned. Dierk. Ver. II, 11(5): 313; 1 female from Salibabu Island, Indonesia.

——— de Man, 1911. Siboga Exped. 39a¹(2): 169, fig. 13 a–c. [Same specimens as the above, with plates.]

Arete amboinensis de Man, 1910. Arch. Naturgesch. 76(1): 25, figs. 1–6; 1 example from Amboina.

Arete intermedius Yu, 1931. Bull. Mus. Hist. Nat., Paris 3(6): 513, fig. 1; one specimen from Amoy, China.

Arete ghardaqensis Ramadan, 1936. Bull. Fac. Sci. Egypt. Univ. 6: 15, pl. 1, fig. 208; 5 specimens from the Red Sea.

Athanas AND *Arete*

According to Coutière's monograph (1899: 322 *et seq.*) the principal differences between *Athanas* and *Arete* lie in the carpus of the second legs, five-jointed in *Athanas* and four-jointed in *Arete;* in the biunguiculation of the dactylus of the third leg in *Arete*, simple in *Athanas;* and in the branchial formula, which contains only six epipodites in *Arete* and seven in *Athanas*. The other differences he cited were mostly differences in proportion, not form. ("Antennules et antennes d'*Athanas*, mais massives et courtes.") With his description of *Athanas areteformis* Coutière felt he had a specimen that showed transition between the two genera. Subsequent description of species by various authors extended the knowledge of differences in form within the two genera, especially in *Athanas*, which, for example, was found to include species with a biunguiculate dactylus.

The two genera have continued to be accepted as separate in spite of the fact that *Athanas areteformis* on one hand and *Arete borradailei* and, later, *Arete ghardaqensis*, on the other hand, lie in a position somewhat intermediate between the two genera. They were still separated on the basis of the carpus of the second legs and on the branchial formula.

This is in spite of the fact that in other genera it has been recognized that the branchial formula varies within a genus, for example in *Betaeus* and *Alpheopsis*, and that the number of carpal articles of the second legs may also vary as in *Alpheopsis* and *Synalpheus*. Kemp (1915: 295) in his description of *Athanus polymorphus* reported that in his specimens the number of carpal articles varied from four to five.

In the present study, the branchial formula of *Athanas djiboutensis* was examined in 17 specimens from one locality on Canton Island, Phoenix group. Because the species is small and the branchial formula is difficult to discern, most specimens were examined on both sides. Only two of the specimens had mastigobranchs on the third thoracic appendages and the setobranchs on the fourth, the branchial formula for the genus; on the other 15 specimens the last masti-

gobranch was on the second maxilliped and the last setobranch (at least in those specimens where it was large enough to be seen) was on the third maxilliped. The two specimens with the more complete set did not differ in any other way from the specimens with the reduced branchial formula. Other specimens from Canton and from other localities were spot checked; most were found with the reduced formula, but occasional individuals carried the more complete set. Thus the more common branchial formula in *Athanas djiboutensis* is the same as that for *Arete*.

Athanas verrucosa Banner, described below, is definitely related to the species known as *Arete borradailei* and *Arete ghardaqensis* in the form of the rostrum, in the form of the large chela, which is unlike those found in other species of either *Athanas* or *Arete*, and in the general configuration of the body and appendages. In fact, even the specific distinctions between these nominal species is in doubt. However, the second legs of *Arete borradailei* and *Arete ghardaqensis* have the four-jointed carpus while *Athanas verrucosa* a five-jointed carpus. It would be unacceptable to place such closely related species in separate genera.

The distinctions, therefore, between *Athanas* and *Arete* have been entirely lost, and *Arete* must be regarded as a synonym of *Athanas*. Further supporting the combination of the two genera is the fact that species in both genera show parallel variation in the form of the large chela with sex and maturity.

Athanas

REDEFINITION: Alpheidae in which the rostrum is well developed; supra-, extra- and infracorneal spines usually present with varying degrees of development; corneas of eyes exposed anteriorly and largely dorsally and laterally; chelae of the first legs well developed, either carried extended or flexed against an expanded merus, usually asymmetric and sexually dimorphic, always without the cylinder and plunger characteristic of *Alpheus;* carpus of second legs with four or five articles; dactylus of third legs simple or bifid; pleura of sixth abdominal segment articulated; telson without anal tubercles, tip arcuate. Branchial formula variable.

DIAGNOSIS: The exposure of the eyes and the form of the large chela separate this genus from *Alpheus, Thunor,* and *Synalpheus;* the articulation of the sixth pleura from *Pterocaris, Automate, Salmoneus, Amphibetaeus, Betaeus* (in part), *Batella, Metabetaeus, Racilius,* and *Pomognathus*. The presence of a rostrum separates the genus from *Betaeus* and *Parabetaeus,* and the exposure of the eyes in dorsal view from *Alpheopsis, Neoalpheopsis* and *Athanopsis*. Finally the lack of high dorsal and ventral keel on the rostrum separates this genus from *Aretopsis*.

TYPE SPECIES: *Palaemon nitescens* Leach, 1814.

VARIATION IN FORM

Because previous workers usually had only a few specimens of each nominal species, most were unaware of the variation that might occur. In the present collections the following species are present in great enough numbers to at least tentatively delimit the extent of variation: *A. areteformis* Coutière, *A. parvus* de Man, *A. djiboutensis* Coutière, *A. marshallensis* Chace, *A. rhotionastes* Banner, *A. dorsalis* (Stimpson), and *A. indicus* (Coutière). Of these only one species, *A. djiboutensis,* the most widespread species both ecologically and geographically, seems to show no marked variation except in the branchial formula, as discussed above, and in the chela. In specimens of this species the form of the rostrum, the teeth about the orbits, and the legs are quite constant. The chelae do show changes in proportion with maturity and sex, but these differences are more slight than in other species. The other species all show marked variation. It is the chelae that have the greatest variation. For example, in the two closely related species, *A. marshallensis* and *A. rhothionastes,* the chelae in the females start out as slender appendages where the merus is not expanded, the palm scarcely broader than the merus, the carpus almost as long as the palm; in this condition the fingers are straight and unarmed (Fig. 2). As the individual grows larger the merus expands to accommodate the chela; the palm grows heavy, the fingers develop strong teeth, the carpus either remains the same length, shortening in relation to adjacent articles, or becomes shorter by actual measure-

ment. In the males a comparable but greater differential growth occurs, so that the fully developed male chela is much heavier than that of the female, with a broader merus and palm, a shorter carpus, and with much heavier teeth on the fingers. In *A. dorsalis* it was found that chelae of the smaller males approached the form of the more mature females, and, in one case, the chela of an extremely large female was quite similar to the normal large males (Fig. 5*e*). This variation was not found to be perfectly correlated with size or maturity; for example, females with a definitely "immature" type of chela were found to be ovigerous, and specimens of the same size from the same locality were found to be of varying development. On all species represented with a sufficient number of specimens this variation was observed, with only *A. djiboutensis* showing it to a more minor extent.

A variation somewhat similar to this was noted by Kemp (1915: 289 *et seq.*) for the males of his species *A. polymorphus*. He had a limited number of specimens and came to the conclusion that breeding activity, not growth, caused the polymorphism. We believe that the evidence given in the following pages indicates that the "polymorphism" must stem primarily from growth. Kemp was also unaware that his variation could be found in other species but he cautioned ". . . it is not unlikely that different forms of the same species have been described under separate names."

More perplexing is the apparent variation in the region of the anterior carapace. In the classification of the species the breadth and length of the rostrum, and the development of supra-, extra- and infracorneal teeth, have been regarded as quite constant and used for specific distinctions. However, in a group of 30 specimens of *A. dorsalis* the tip of the rostrum was found to reach from the end of the first antennular article to the middle of the third antennular article; in the same group of specimens the extracorneal teeth were usually well developed and acute, but in one they were lacking. In *A. areteformis* some specimens carried an infracorneal tooth of varying development, some did not (in three specimens from the same location two are without teeth, the third with a small infracorneal tooth bilaterally developed).

To the contrary *A. marshallensis, A. rhothionastes,* and *A. djiboutensis* all present in some numbers in the collections, are quite uniform in the development of these parts. It would appear that some species are inherently more variable than others, a condition found in members of the genus *Alpheus*.

Finally, in *A. dorsalis* the development of the tooth on the merus of the third legs and the proportions of articles of this leg were also found to vary. Like species in other genera of the family, the telson also varies in its proportions.

These variations will be discussed more fully for each species in the following section.

These variations in parts previously considered to be of taxonomic importance render it difficult to decide upon a valid basis for species differentiation. A possible clue to aid systematists may be found in the ecology of the forms being considered. At least in two pairs of closely related species the most valuable clue is their environment. *A. dorsalis* appears to be usually, if not always, associated with sea urchins of the genus *Heterocentrotus*, while the closely related *A. indicus* with the sea urchins of the genus *Echinometra;* again in the closely related pair, *A. marshallensis* and *A. rhothionastes, A. marshallensis* appears to be found only in the silty sandy shorelines of lagoons, associated with *Alpheus strenuus* Dana (whether it is a symbiotic association or a mere ecological association is not known), while *A. rhothionastes* has been found almost exclusively on the coralline ridge of seaward reefs where it is subjected to heavy surf. This type of aid, however, is also questionable, for *A. djiboutensis* is widespread in its environments; most were collected from either the inner zone of outer reefs on islands, especially on the lee side of an island, or from somewhat similar conditions on the lagoon beaches of an atoll; some, however, were collected from near the surf line.

With so much variation, with the extent of this variation apparently inconstant from species to species, and with so many species described on the basis of one or several individuals, it is impossible to decide which species put into the

two genera should be regarded as valid. In the following key we have not combined any species for which we have no specimens. We also do not include the few non-Indo-Pacific species, but we do include those species from the Pacific that are nontropical.

KEY TO THE INDO-PACIFIC SPECIES OF *Athanas*[3]

1. Palm of large chela cylindrical or subcylindrical in section; carpus of second legs with five articles ... 2
   Palm of large chela flattened, definitely higher than broad in section, carpus of second legs with four or five articles ... 22
2(1). Legs of first pair, when fully developed, carried directed forward; merus short, not excavate ... 3
   Legs of first pair, when fully developed, with chelae carried folded against an excavate and expanded merus ... 6
3(2). Supracorneal teeth present ... *A. areteformis* Coutière[4]
   Supracorneal teeth absent ... 4
4(3). Dactylus of third legs biunguiculate ... **A. granti** Coutière
   Dactylus of third legs simple, but may carry an articulated spinule at usual point of biunguiculation ... 5
5(4). Dactylus of third legs simple; with both extra- and infracorneal teeth ... **A. crosslandi** Tattersall
   Dactylus of third leg carrying an articulated spinule; with only extracorneal teeth (originally described as infracorneal teeth) ... **A. gracilis** Boone
6(2). Supracorneal teeth present ... *A. djiboutensis* Coutière
   Supracorneal teeth absent ... 7
7(6). Dactylus of third leg biunguiculate ... 8
   Dactylus of third leg simple ... 9
8(7). With infracorneal tooth ... *A. parvus* de Man
   Without infracorneal tooth or projection ... **A. jedanensis** de Man
9(7). Carpus of first leg longer than palm in mature females ... 10
   Carpus of first legs equal in length to palm, or shorter, in mature females ... 15
10(9). Ischium of first legs with strong distal spine ... **A. orientalis** Pearson
   Ischium of first legs not so armed ... 11
11(10). Palm of chela in female less than 1.5 times length of fingers ... 12
   Palm of chela in female 2.0 or more times length of fingers ... 13
12(11). Palm of chela in female shorter than fingers; stylocerite reaching to end of third antennular article; dactylus of third legs one-third length of propodus ... **A. setoensis** Kubo
   Palm in female equal to fingers; stylocerite reaching slightly past end of first antennular article; dactylus of third legs more than half length of propodus ... **A. polymorphus** Kemp
13(11). With extracorneal tooth strong and acute; infracorneal projection almost as long as extracorneal tooth, but rounded ... **A. stebbingi** de Man
   With only extracorneal tooth (or infracorneal tooth) produced and acute ... 14
14(13). Rostrum reaching to end of second antennular article ... **A. dimorphus** Ortmann
   Rostrum a little longer than antennular peduncle ... **A. monoceros** (Heller)
15(9). Infracorneal projection at most slight and rounded ... 16
   Infracorneal projection present and acute ... 18

[3] *Athanas tenuipes* de Man is omitted from the key as the type specimen, the only specimen known, lacked both legs of the first pair. Otherwise, it is characterized by five articles in the carpus of the second legs, the lack of supracorneal teeth, the presence of extra- and infracorneal teeth; its rostrum reaches to the middle of the second antennular article; and third legs and telson of slender and elongate form.

[4] Those species whose names are in italic are discussed in this paper.

16(15). Rostrum reaching to end of antennular peduncle ..... **A. lamellifer** Kubo

Rostrum at most reaching to end of second antennular article, usually shorter 17

17(16). Palm of chelae 2.5 times length of carpus, or shorter, in mature females..... *A. marshallensis* Chace

Palm of chelae 3 to 5 times length of carpus in mature females..... *A. rhothionastes* Banner

18(15). Infracorneal tooth longer than extracorneal tooth 19

Infracorneal tooth shorter than extracorneal tooth 20

19(18). Dorsal carina extending along anterior half of carapace and rostrum..... **A. japonicus** Kubo

Anterior carapace without dorsal carina..... *A. esakii* Kubo

20(18). Dactylus of large chela of male strongly curved, "half-moon shaped," much longer than fixed finger..... **A. oshimae** Yokoya

Dactylus of large chela of male at most slightly curved, not "half-moon shaped," not markedly longer than fixed finger (males unknown in *A. haswelli* below)..21

21(20). Carpus and chelae slender in females[5]..... **A. haswelli** Coutière

Carpus and chelae of females more robust[5]..... **A. minikoensis** Coutière

22(1). With well-developed supracorneal teeth 23

Without trace of supracorneal teeth; carpus of second legs with four articles 25

23(22). With carpus of second legs with five articles, lower portion of palm of large chela bearing numerous papillae..... *A. verrucosus* Banner

With carpus of second legs with four articles; lower portion of palm of large chela without papillae 24

24(23). Ventral side of rostrum smoothly convex; base of outer flagellum with four articles; propodal spine of uropod simple..... **A. borradailei** (Coutière)

Ventral side of rostrum with an obtuse angle; base of outer antennular flagellum with more than four articles; propodal spine of uropod bifid ..... **A. ghardaqensis** (Ramadan)

25(22). Rostrum reaching to middle or end of third article of antennular peduncle. Usually associated with sea urchins of the genus *Echinometra*..... *A. indicus* (Coutière)

Rostrum not reaching past middle of second antennular article, usually only to end of first article or shorter 26

26(25). Telson elongate, 6.5 times as long as posterior margin is broad; posterior margin one-third breadth of base. Symbiotic association, if any, unrecorded..... **A. amboinensis** (de Man)

Telson less than 4 times as long as posterior margin is broad; posterior margin one-fourth to one-fifth breadth of base. Usually associated with sea urchins of the genus *Heterocentrotus* ..... *A. dorsalis* (Stimpson)

[5] Coutière's only differentiation between these two species is as follows: "[The cheliped of *A. haswelli*] a la même forme cylindrique et grêle [as *A. dimorphus*] ce qui distingue l'espèce de l'*A. minikoensis* où la pince est beaucoup plus robust et le carpe court." Bull. Soc. Philom. IX, 11(5): 2. 1908.

Athanas areteformis Coutière

Athanas naifaroensis Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 77, figs. 14–16; [same description and figures in 1905, Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 859, fig. 131 a–c].

Athanas areteformis Coutière, 1903. *Op. cit.* p. 79, figs. 17–19; [same description and figures in 1905, *op. cit.*, p. 860, fig. 132 a–c].

Athanas erythraeus Ramadan, 1936. Bull. Fac. Sci. Egypt. Univ. 6: 13, pl. 1, fig. 1.

Athanas dubius Banner, 1956. Pacif. Sci. 10(3): 323, fig. 2a–h.

DISCUSSION: These four nominal species were all described on the basis of a few specimens, as listed in the introduction: Coutière had two females, one incomplete, for *A. naifaroensis;* one complete male and one incomplete female for *A. areteformis;* Ramadan had one female for *A. erythraeus;* I had nine specimens from Saipan. Since the original description several more specimens have been reported for *A. areteformis* (Chace, 1955: 21; Balss, 1915: 30) and for *A. naifaroensis* (de Man, 1922: 16; Barnard, 1950: 731) and no more specimens have been reported for *A. erythraeus.*

The four species were separated by various characteristics. *A. naifaroensis* differed from *A. areteformis* seemingly only in the presence of infracorneal spines (the chela of the male had never been observed). For his species, Ramadan listed a number of differences that would distinguish it from *A. areteformis:* 1. The visible portion of the first article of the antennular peduncle he stated was considerably longer than the sum of the other two in *A. areteformis* and about equal to the sum in *A. erythraeus.* Apparently this is in error, for Coutière does not state or show such a relationship, and in specimens that are plainly *A. areteformis* the relationship is as it is described for *A. erythraeus.* 2. The lateral corneal spine "is not as well developed" in *A. erythraeus* as in *A. areteformis.* 3. The chela of the female in *A. erythraeus* is like that of the male *A. areteformis* (although Ramadan's plate does not show this condition); the dactyl and fixed finger had low teeth.

A. dubius was distinguished from *A. areteformis* principally by the forms of the male and female chelae with the fingers on the male being slender and straight more like the female *A. areteformis,* and the palm on the female being broader; also the ischium on the male and female carried spines which apparently were lacking in the female *A. areteformis.*

In the present collections there are 25 specimens that can be referred to this complex; unfortunately, many of them are small or incomplete.

These specimens are found to be variable in all characteristics that have been used for the separation of these species. The rostrum reaches from near the end of the second antennular article to the middle of the third; in some the basal portion has parallel sides, in others the rostrum has an almost uniform taper to the tip. The supracorneal teeth are well developed and acute in some, while in others they are shorter and more rounded, like the condition depicted for *A. dubius;* the cleavage between the base of the rostrum and supracorneal spines also varies in depth and definition. All but five specimens lack the infracorneal tooth; however, on these five the tooth varies from considerably smaller to larger than that depicted for *A. naifaroensis.* In the collection are three specimens from Tonga from the same location, two without teeth and the third carrying a small but definite tooth.

Similar variations can be seen in the length ratios of the antennular articles, and at least within narrow limits, in the development of the lateral spine of the scaphocerite.

In the series many of the specimens lack the chelae. The females all show the type illustrated for *A. naifaroensis* and *A. dubius.* In this appendage the merus varies from 2.5 to 3.3 times as long as broad, with the two sides showing asymmetry and the larger specimens in general with the higher ratios; the length-breadth ratio of the carpus runs from 0.7 to 1.1; the palm, 2.0 to 2.7; the palm varies from 1.3 to 1.8 times the length of the fingers. All specimens have from three to five spines on the ischium. One female of 3.3 mm. carapace length had slight teeth on the dactylus, similar to those described by Ramadan.

Of the males all specimens but one also had a chela as described for *A. dubius* and female of *A. areteformis* with a slender merus, with the length from 1.6 to 3.0 times the breadth; the carpus somewhat elongate, 0.8 to 1.0 times as long as broad; the palm from 1.4 to 2.6 times as long as broad, and the palm 1.4 to 1.8 times the length of the fingers. However, the largest of all males, with a carapace length of 3.2 mm. had the form described for the male *A. areteformis,* with short curved fingers, a heavy cylindrical palm 3.3 times the length of the fingers. This specimen came from the same collection (BE-11) as did two larger females and a small male (carapace length of 2.2 mm.) with a typically

TABLE 1
VARIATION IN PROPORTIONS IN THE CHELAE OF *Athanas djiboutensis* COUTIÈRE

LOCALITY	SEX	CARAPACE LENGTH	SMALL CHELA						LARGE CHELA					
			Fingers	Palm	Carpus	Merus	Merus 1/b	Carpus 1/b	Fingers	Palm	Carpus	Merus	Merus 1/b	Carpus 1/b
			(in proportion to palm)						(in proportion to palm)					
Tahiti	♀	2.7 mm.	0.8	1.0	1.0	1.6	—	—	0.4	1.0	0.2	1.0	—	—
Tahiti	♀	2.7 mm.	1.0	1.0	1.4	2.0	1.6	2.3	0.5	1.0	0.2	1.2	3.0	1.2
Tonga	♀	3.0 mm.	0.8	1.0	1.1	1.8	1.7	2.7	0.4	1.0	0.2	0.9	4.0	1.7
Samoa	♀	3.0 mm.	0.7	1.0	0.9	1.5	2.7	2.0	0.4	1.0	0.2	1.2	5.0	1.6
Canton	♀	3.0 mm.	0.8	1.0	2.0	1.8	4.0	4.0	0.4	1.0	0.2	1.0	2.0	—
Samoa	♀	3.4 mm.	0.8	1.0	1.1	2.0	3.5	2.0	0.4	1.0	0.2	1.0	4.3	1.1
Tonga	♀	3.5 mm.	0.7	1.0	1.2	1.6	3.0	2.5	0.3	1.0	0.2	1.0	4.6	1.4
Tonga	♀	3.6 mm.	—	—	—	—	—	—	0.3	1.0	0.2	1.2	4.1	0.7
Samoa	♂	2.1 mm.	0.8	1.0	0.8	1.4	3.5	2.0	0.4	1.0	0.3	1.0	5.2	1.2
Tahiti	♂	2.2 mm.	0.8	1.0	0.9	1.8	3.0	1.5	0.4	1.0	0.4	1.2	3.0	1.1
Tahiti	♂	2.4 mm.	0.7	1.0	0.3	1.2	—	—	0.3	1.0	0.2	1.1	3.0	1.8
Samoa	♂	2.4 mm.	0.6	1.0	0.9	1.6	2.0	1.6	—	—	—	—	—	—
Samoa	♂	2.4 mm.	0.8	1.0	1.1	1.6	2.6	2.0	0.4	1.0	0.2	1.0	2.5	1.1
Tahiti	♂	2.4 mm.	0.8	1.0	1.0	1.6	1.3	2.5	—	—	—	—	—	—
Fiji	♂	2.5 mm.	—	—	—	—	—	—	0.4	1.0	0.3	1.2	2.2	1.0
Eniwetok	♂	2.7 mm.	0.6	1.0	0.3	1.2	2.5	1.4	0.3	1.0	0.3	1.0	2.2	1.0
Eniwetok	♂	2.7 mm.	0.6	1.0	0.6	1.8	2.6	1.6	0.4	1.0	0.3	1.0	2.1	1.0
Eniwetok	♂	2.8 mm.	0.4	1.0	0.3	1.3	3.8	1.0	0.4	1.0	0.2	1.0	2.4	1.0
Samoa	♂	2.8 mm.	0.5	1.0	0.3	1.4	2.8	1.0	0.4	1.0	0.1	1.0	2.3	1.0
Eniwetok	♂	3.1 mm.	0.4	1.0	0.3	0.9	2.4	1.0	0.2	1.0	0.1	0.8	2.9	1.0
Samoa	♂	3.2 mm.	0.5	1.0	0.2	1.3	2.3	0.9	0.3	1.0	0.3	1.1	2.0	1.5
Samoa	♂	3.4 mm.	0.5	1.0	0.2	1.5	2.6	1.0	0.3	1.0	0.2	0.9	2.1	1.1
Samoa	♂	3.6 mm.	0.6	1.0	0.2	1.3	2.3	1.0	0.3	1.0	0.2	0.9	2.1	0.9
Samoa	♂	3.9 mm.	0.6	1.0	0.3	1.3	2.4	1.4	0.3	1.0	0.2	1.0	2.2	1.2

feminine chela. This variation in the chelae is similar to that of other members of the genus.

With these variations the distinctions between the four nominal species have disappeared. As the original description of *A. areteformis* carries the description and figure of the characteristic chela of the male, we have chosen to retain that name rather than the name *A. naifaroensis*, which would have to be selected were strict page priority to be followed.

DISTRIBUTION: These specimens have been reported from South Africa, the Red Sea, the Maldive and Laccadive Archipelagoes, and the Marianas. Specimens in the present collections were collected from various places on reef flats and fronts, lagoons, lee and windward reefs at varying depths. There is one specimen for Fiji, four from Tonga, one from British Samoa, four from the Cook Islands, three from the Society Islands, and five specimens from the Marshall Islands.

Athanas djiboutensis Coutière

Athanas djiboutensis Coutière, 1897. Bull. Mus. Hist. Nat., Paris 3(6):233.

Athanas sulcatipes Borradaile, 1898. Proc. Zool. Soc. Lond., p. 1011, pl. 65, fig. 9.

DISCUSSION: As discussed in the introductory section this widespread and common species is quite constant in its characteristics except for the branchial formula and the growth and sexual differences of the large chela. Some minor differences in length of the rostrum are found, as was discussed for the Saipan specimens (Banner, 1956: 322).

In Table 1 below, the proportions of the male and female chelae are given for specimens taken at random from the collections and arranged according to carapace length. The changes of proportions with sex and growth are clearly shown, and the variation between specimens of nearly the same size does not appear to be from

geographical races, but variation of the type that could be found within a single population.

DISTRIBUTION: This species has been previously reported from the Red Sea, Mozambique, Maldive Archipelago, Christmas Island (Indian Ocean), Indonesia, Great Barrier Reef, Mariana Archipelago, Marshall Islands, Wake Island, Ellice Islands, Samoa, Tuamotus, and the Marquesas. In the present collections specimens are from the Caroline Islands, Marshall Islands, Phoenix Islands, Fiji, Tonga, Samoa, Cook Islands and Tahiti.

Athanas parvus de Man
Fig. 1

Athanas parvus de Man, 1910*a*. Tijdschr. Ned. Dierk. Ver. II, 11(2): 315. [Additional description and figures in Siboga Exped. 39a[1] (2): 148, fig. 4a-d.]

Athanas parvus de Man, Kubo, 1940*b*. Annot. Zool. Jap. 19(2): 99, figs. 1, 2. [Additional description.]

Athanas sibogae de Man, 1910*a*. Tijdschr. Ned. Dierk. Ver. II, 11(2): 314. [Additional description and figures in Siboga Exped. 39a[1] (2): 151, fig. 6a–h.]

DISCUSSION: Unfortunately, none of our eleven specimens are complete. The carapace and the intact appendages agree well with the published descriptions of *Athanas parvus*. There are the usual slight differences in proportions—for example, the merus of the third legs usually runs about 5 times as long as broad instead of 7—but these differences, like those given by Kubo, appear to be of no taxonomic importance.

One male only had a chela intact; it is not known whether this is the larger or smaller, or if they are of symmetrical development. However, as the chela of the male has never been described, it is shown in Figure 1. In it the ischium is rather long and slender; the merus is 3.4 times as long as broad, excavate along the lower margin to accommodate the chela when flexed; the carpus is short and not distally expanded; the palm is slender and tapering, 2.5 times as long as broad, without grooves or ridges; the dactylus has been broken, but the remaining portion of it and the fixed finger are quite straight and bear a series of low, conical teeth. Presumably this is not the fully mature stage of the chela, and in this condition it resembles the chela described for *A. jedanensis* de Man.

A. parvus was previously placed into the Nitescens group of the genus because the chela described for the female, which may be immature, were carried extended; this male shows that its rightful position is in the Dimorphus group. With this differentiating character removed only very slight differences can be found between this species and *A. sibogae*. There is a slight difference in the infracorneal tooth, the chelae appear to be different and the lower unguis of the dactylus of the third leg is heavier and make a greater angle to the dactylus in this species than it does in *A. sibogae*. With the great differences in other species, especially in *A. areteformis*, in the development of the orbital teeth, and with the growth and sex differences in the chela in this genus, the first two characteristics cannot be regarded as sufficient for specific separation; the difference in development of the dactyls is so slight that that too cannot be relied upon. The two species later may be found to be distinct, but with the present knowledge of inherent variation within this

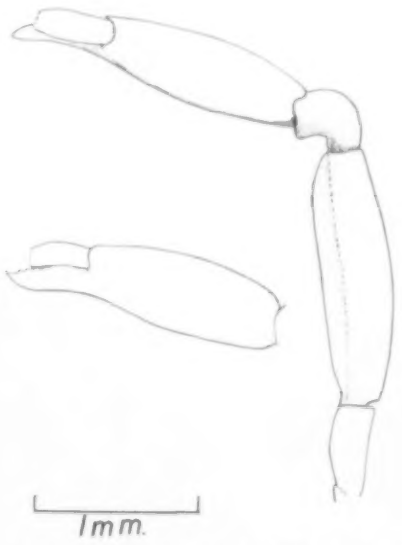


FIG. 1. *Athanas parvus* de Man. Chela of male from Samoa (BBS-10); tip of dactylus lost in specimen.

TABLE 2
VARIATIONS IN THE CHELAE OF *Athanas marshallensis* CHACE

SEX	CARAPACE LENGTH	LEFT CHELA						RIGHT CHELA					
		Fingers	Palm	Carpus	Merus	Merus 1/b	Palm 1/b	Fingers	Palm	Carpus	Merus	Merus 1/b	Palm 1/b
		(in proportion to palm)						(in proportion to palm)					
♀	3.1 mm.	0.6	1.0	1.0	1.4	4.0	2.7	0.5	1.0	1.1	1.5	3.7	2.5
♀	3.5 mm.	0.5	1.0	0.8	1.2	3.8	3.0	0.4	1.0	0.6	1.2	3.8	3.6
♀	3.6 mm.	0.5	1.0	1.0	1.4	4.0	3.4	0.4	1.0	0.6	1.2	4.0	3.3
♀	3.7 mm.	0.3	1.0	0.9	1.3	4.5	3.5	0.3	1.0	0.8	1.3	3.8	2.8
♀	4.5 mm.	0.3	1.0	0.4	1.0	3.0	3.0	0.3	1.0	0.6	1.1	3.3	3.7
♀	4.6 mm.	0.4	1.0	0.8	1.4	3.5	3.1	0.3	1.0	0.6	1.2	3.2	3.4
♀	5.2 mm.	0.4	1.0	0.4	1.1	3.3	3.1	0.4	1.0	0.4	0.9	3.0	3.2
♂	4.3 mm.	0.3	1.0	0.2	0.9	3.0	2.7	0.2	1.0	0.2	0.9	2.8	3.0
♂	4.6 mm.	0.2	1.0	0.2	0.9	2.5	3.0	0.2	1.0	0.2	0.9	2.5	3.0
♂	5.3 mm.	0.3	1.0	0.3	1.0	2.7	2.3	0.3	1.0	0.2	0.9	2.5	3.2

genus, it appears wiser to place *A. sibogae* in synonymy.

Indeed, *A. jedanensis* may also be found to be a synonym. In this species the chief distinction, when the differences in the chelae are ruled out, is the absence of the infracorneal spine. If this is variable, as it is in *A. areteformis*, then there is but one species. However, as in this small collection no transitional forms were found, *A. jedanensis* has been retained.

DISTRIBUTION: *A. parvus* has been reported from the type locality, in Indonesia, and from southern Japan; *A. sibogae* only from Indonesia. Specimens in the present collections came from various places on the reef flats in from 1 to 6 feet of water and were largely from dead coral heads. There were seven specimens from Tonga, and four from Samoa.

Athanas marshallensis Chace
Fig. 2

Athanas marshallensis Chace, 1955. Proc. U. S. Nat. Mus. 105(3349): 17–20, fig. 8.

DISCUSSION: All the 11 specimens available were collected in a single narrow habitat at Eniwetok, Marshall Islands, under loose coral boulders resting on a sandy substrate in the intertidal zone where they were collected together with *Alpheus strenuus* Dana, *Salmoneus tricristatus* Banner, and *S. sibogae* (de Man). It is noteworthy that in similar habitats in other archipelagoes producing widespread *A. strenuus* this species was not collected; all specimens known have been collected solely from the northern Marshall Islands.

In this series of specimens the usual changes in form of the chelae with size and sex are found. Table 2 gives the changes in proportion with size of all specimens collected; Figure 2*b–d* shows the changes with growth in the female and the chela of a mature male for contrast. The proportions show that the chelae of the large male are quite symmetrical; it is possible that the chelae of very large females, larger than those represented in the collection, may also become symmetrical.

The differences between this species and *A. rhothionastes* Banner are discussed under the latter species. This species may prove to be a synonym of *A. esakii* Kubo but at present the two forms appear to be distinct; this is discussed under *A. esakii*.

DISTRIBUTION: As stated above all specimens of this species have been collected from the northern Marshall Islands.

Athanas rhothionastes sp. nov.
Fig. 3

TYPE SPECIMENS: Holotype, a 12 mm. (4.8 mm. carapace length) ovigerous female; allotype, a male of the same size; paratypes from the same locality, at end of surge channels, edge of reef front, leeward (western) side, Canton

Island, Phoenix group, collected by A. H. Banner 1 March 1954. Additional specimens from Eniwetok, Vitilevu, Tongatabu, Opolu, Tutuila, Aitutake, and Tahiti, all from surf zone on reef fronts except for one specimen from the lagoon at Eniwetok (BE-2); this, however, must have been subject to surge for it came from the base of *Pocillopora meandrina* Verrill, a coral that never lives in still waters.

DESCRIPTION: Rostrum acute with sides of uniform taper or with slight "jog" in lateral margins anterior to eyes; tip reaching to middle of second antennular article; slight carina in anterior half. Supracorneal teeth lacking; extracorneal teeth acute, reaching almost to end of corneas; infracorneal projection short and rounded; pterygostomial corner rounded. Corneas of eyes concealed in posterior portion and laterally by extra- and infracorneal projections.

Antennular peduncle short and heavy, with first, second and third articles subequal in length, second article as broad as long. Stylocerite long, lanceolate, tip reaching to near end of third antennular article. Scaphocerite broad and long, tip reaching beyond end of antennular peduncle; lateral spine strong, slightly exceeding squamous portion in length. Basicerite unarmed. Carpocerite reaching about to end of antennular peduncle.

Chelae of large female symmetrical. Ischium bearing four strong spines on superior margin. Merus 3.2 times as long as broad, unarmed; superior external and internal surfaces smooth and flat; inferior surface deeply excavate to accommodate propodus, short, 0.2 to 0.3 length of palm (depending upon place measured), normally greatly flexed. Palm subcylindrical, 3.5 times as long as broad, equal in length to merus, tapering slightly towards fingers; dactylus curved, one-quarter as long as palm with irregular, large rounded teeth matching exactly with teeth on fixed finger. Chelae in allotype of same carapace length considerably larger and slightly asymmetrical with the right almost 10 per cent larger than the left; in both male chelae, merus and palm are markedly thicker than those of the female. Armature of fingers poorly developed in smaller chela; on large chela fixed finger bearing single large rounded tooth and smaller tooth proximally, dactylus bearing two teeth in

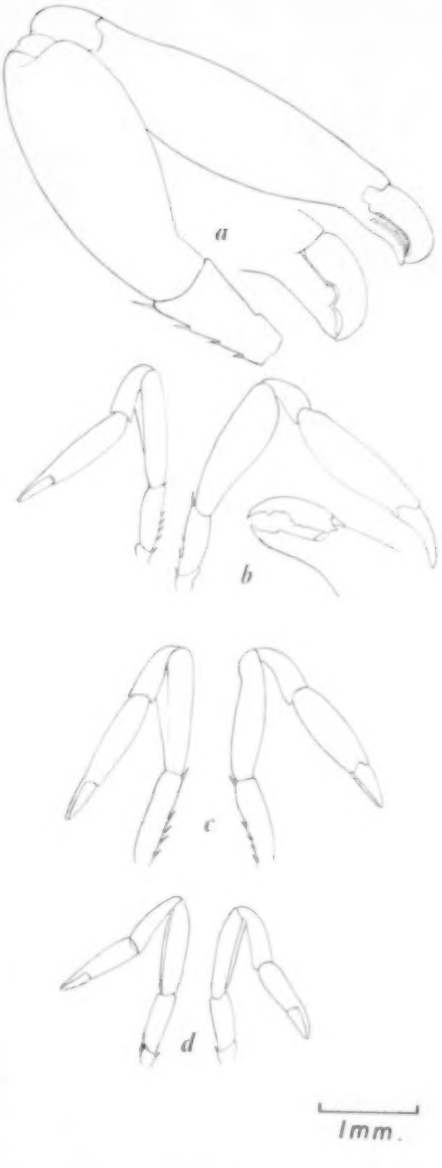


FIG. 2. *Athanas marshallensis* Chace. Chelipeds of various individuals from Eniwetok. *a*, 4.6 mm. ♂; *b*, 4.5 mm. ♀; *c*, 3.7 mm. ♀; *d*, 3.1 mm. ♀. (All to same scale.)

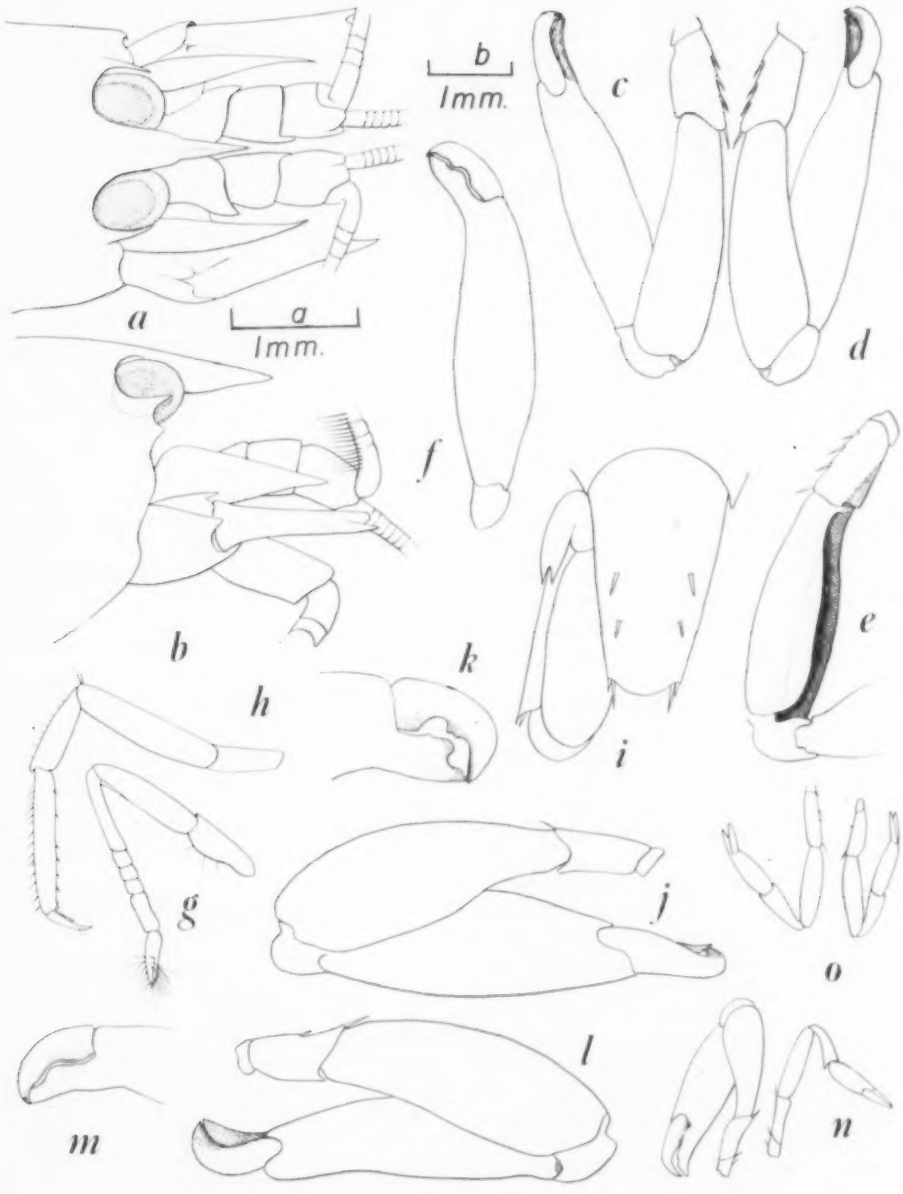

a
a
1mm.
b
1mm.
c
d
f
b
h
k
i
e
g
j
o
m
l
n

TABLE 3
VARIATION IN THE CHELIPEDS OF *Athanas rhothionastes* SP. NOV.

LOCALITY	SEX	CARAPACE LENGTH	SMALL CHELA							LARGE CHELA						
			Fingers (in proportion to palm)	Palm	Carpus	Merus	Palm 1/b	Carpus 1/b	Merus 1/b	Fingers (in proportion to palm)	Palm	Carpus	Merus	Palm 1/b	Carpus 1/b	Merus 1/b
Tahiti	♀	2.8 mm.	0.5	1.0	1.6	1.4	2.7	2.5	3.2	0.4	1.0	0.2	0.8	2.7	1.2	2.8
Tahiti	♀	3.2 mm.	0.3	1.0	0.2	1.0	2.6	1.3	2.5	0.4	1.0	0.2	0.8	2.7	1.2	2.5
Tahiti	♀	3.4 mm.	—	—	—	—	—	—	—	0.4	1.0	0.2	1.0	2.8	1.5	2.8
Canton	♀	3.8 mm.	0.3	1.0	0.2	0.8	2.9	1.2	2.8	0.4	1.0	0.2	1.0	3.1	1.4	3.2
Canton	♀	3.9 mm.	0.3	1.0	0.2	0.8	3.0	1.3	3.0	0.3	1.0	0.2	0.9	2.8	1.1	3.6
Eniwetok	♀	4.1 mm.	0.4	1.0	0.2	0.9	2.7	1.4	2.9	0.3	1.0	0.2	0.9	2.6	1.5	2.7
Canton	♀	4.3 mm.	0.4	1.0	0.2	1.0	2.7	1.3	2.7	—	—	—	—	—	—	—
Canton	♀	4.5 mm.	0.4	1.0	0.3	1.1	2.6	1.8	2.8	—	—	—	—	—	—	—
Samoa	♂	2.7 mm.	—	—	—	—	—	—	—	0.4	1.0	0.3	1.1	2.8	1.8	3.2
Tahiti	♂	2.8 mm.	0.3	1.0	0.3	1.0	3.0	1.5	2.7	0.4	1.0	0.2	0.9	2.5	1.0	2.5
Fiji	♂	3.2 mm.	—	—	—	—	—	—	—	0.2	1.0	0.2	0.9	3.0	1.6	2.4
Tonga	♂	3.4 mm.	0.3	1.0	0.2	0.9	2.9	1.6	2.6	0.3	1.0	0.2	0.9	2.6	1.6	2.9
Canton	♂	3.4 mm.	0.4	1.0	0.2	1.0	2.8	1.5	3.3	0.3	1.0	0.2	0.9	2.9	1.3	2.5
Tahiti	♂	3.5 mm.	0.3	1.0	0.1	0.9	3.2	1.6	3.0	—	—	—	—	—	—	—
Tahiti	♂	3.7 mm.	0.3	1.0	0.2	1.1	2.7	1.0	2.9	0.3	1.0	0.2	1.0	3.1	1.2	2.8
Canton	♂	4.2 mm.	—	—	—	—	—	—	—	0.2	1.0	0.2	0.9	3.1	1.0	2.1
Canton	♂	4.3 mm.	0.3	1.0	0.2	1.0	3.0	1.5	2.4	0.3	1.0	0.2	0.9	2.5	0.9	2.4

opposition to large tooth (evidently these are thin and used for cutting as they slide past each other).

Carpal articles of second leg with ratio: 10: 1: 1: 1: 5.

Ischium of third legs unarmed, 0.4 as long as merus; merus unarmed, 5 times as long as broad; superior distal margin of carpus projecting but rounded, carpus 0.5 as long as merus; propodus 0.9 as long as merus, armed with scattered spines along inferior margin; dactylus slender, slightly curved, acute and simple, and 0.3 as long as propodus.

Telson 3.3 times as long as broad distally, twice as broad proximally as distally; lateral margins with uniform taper; tip broadly arcuate; dorsal and terminal spinules normal. Uropods longer than telson, outer uropod armed with tooth and movable spine at articulation.

Color in life not noted.

DISCUSSION: Variation in this series of specimens has been carefully studied to determine if they are distinct from closely related species. The rostrum is always acute, almost always tapering, although there are a few with straight parallel sides in the proximal third to half; the tip reaches from the middle to the end of the second antennular article except for a very small specimen from Samoa, where the tip reaches to the middle of the third antennular article. In many, the rostrum appears more narrow than in the holotype and often has a slight upturn towards the tip when seen in side view. Likewise, with few exceptions, the extra- and infracorneal projections are quite uniform; in the small specimens from Samoa assigned to this species the infracorneal tooth is almost acute; in one from the type locality the extracorneal tooth is bifid on one side and with the infracorneal projection rounded but on the other side in the same specimen the upper tooth is normal and the infracorneal tooth is acute.

FIG. 3. *Athanas rhothionastes* Banner. Holotype (female) *a-i;* allotype *j-m. a, b,* Anterior region; *c, d, e, f,* chelipeds; *f,* interior lateral surface of chelae; *g,* second leg; *h,* third leg; *i,* telson; *j, k,* large cheliped and fingers; *l, m,* small cheliped and fingers; *n,* large and small chelae of 2.7 mm. (carapace length) ovigerous female from Tahiti (BD-2); *o,* same from 3.0 mm. ovigerous female from Eniwetok (BE-4). (Anterior body region and telson, scale a; all other appendages scale b.)

The proportions of the chelipeds are given in Table 3. The 2.7 mm. female from Tahiti with the asymmetrical chela (Fig. 3*n*) is almost certain to belong to this species, for it was collected with larger specimens of the species with normal chelae. There may be some question about the 3.0 mm. female from Eniwetok (Fig. 3*o*) for it was collected alone and its rostrum had been broken. However, as its chelae could represent an earlier stage of development, as it agrees with the species on other characteristics, and as it was collected from the typical habitat of this species, we believe we can safely assume it to belong to *A. rhothionastes*. The development of ischial spines of the chelipeds appears to be variable.

If these two smallest specimens given in the table do belong to this species, then here again we have the variation on the chelipeds with age and sex that seems to be characteristic of so many species of this genus. The degree of uniformity in the rostrum and corneal spines casts some doubt upon the uniting of species like *A. naifaroensis* and *A. areteformis* (see previous sections).

A. rhothionastes is closely related, morphologically, to two species, *A. lamellifer* Kubo and *A. marshallensis* Chace. This group of species of the Dimorphus group are characterized by the lack of supracorneal teeth, acute extracorneal teeth, rounded infracorneal teeth, with the palm definitely longer than the carpus in mature females, and with simple dactyli of the third legs. The distinction between this species and *A. lamellifer* is fine and questionable, for the chief differences lie in the length of the rostrum, which exceeds the length of the antennular peduncle in *A. lamellifer* and usually reaches only to the end of the second antennular article in *A. rhothionastes*, and in the armature of the fingers of the large chela of the male, bearing merely setae in Kubo's species and bearing heavy teeth and setae in this species. The ischium of the cheliped of *A. rhothionastes* appears consistently longer than that reported by Kubo. The carpus of the cheliped is consistently longer in *A. marshallensis* than in *A. rhothionastes* in the immature stages and in the fully developed females; there are no obvious differences between the males of the two species.

Possibly better than the morphological differentiation between the three species would be the ecological differences. *A. rhothionastes* so far as had been collected always occurs in regions of surge or heavy surf on coral reefs, usually on the outermost reef fronts in the coralline ridge and near the end of the surge channels; *A. lamellifer* has been reported only from the colder waters of Tokyo Bay (Tiba Prefecture of Kubo is now transliterated Chika) under stones on a muddy shore, and while there was nothing in the original listing for *A. marshallensis* that would indicate ecology, all specimens I have collected from Eniwetok, the type locality, came from under rocks on a sandy bottom in a somewhat protected cove on the lagoon side of one of the islets.

The specific name is derived from the Greek *rhothion*, meaning breakers or surf, and *nastes*, meaning inhabitant.

Athanas esakii Kubo

Athanas esakii Kubo, 1940*a*. J. Fish. Inst. Tokyo 34(1): 93–95, fig. 13*a–p*.

DISCUSSION: This small and obviously immature specimen was collected with numerous and larger specimens of *A. marshallensis* Chace apparently in a single ecological niche. On the basis of ecology, therefore, the separation of the two species is doubtful.

The specimen appears to be distinct from *A. marshallensis* only in the presence of an acute infracorneal tooth, all traces of which are lacking in *A. marshallensis*. While this characteristic does not appear to be reliable in other species of this genus, as in *A. areteformis*, the lack of intergrading specimens would make the placement of *A. marshallensis* in synonymy at this time a questionable step.

The chelae of this specimen are not exactly like either *A. marshallensis* nor *A. esakii*, but sufficiently close to both that the differences could easily be the result of immaturity. In this specimen the chelae have the following proportions:

	Merus	Carpus	Palm	Fingers
Smaller chela	1.5	1.0	1.0	0.6
Larger chela	1.3	0.8	1.0	0.5

Kubo reported that in his female specimen, somewhat larger than this, the chelae were noticeably asymmetrical; in this specimen the chelae were almost the same size.

DISTRIBUTION: Kubo's specimens came from Kusaie in the Caroline Islands while our specimen came from Eniwetok and was found under a boulder in the sand on the lagoon side of an islet.

Athanas verrucosus sp. nov.
Fig. 4

TYPE SPECIMEN: An ovigerous female, carapace length of 3.9 mm., total length of 11 mm., collected from coralline ridge, ocean (windward) reef, Parry Island, Eniwetok, 3 March 1957, by A. H. Banner (station BE-23). Sole specimen known.

DESCRIPTION: Body form usual. Rostrum short, reaching about to end of first antennular article; acute in dorsal view, triangular with straight sides; in lateral view with dorsal margin curved upward towards tip, ventral margin with double curve and bearing small tuft of setae; rostrum and carapace without carina. Supracorneal teeth distinct, acute, reaching almost to end of cornea; extracorneal teeth larger, exceeding length of cornea; infracorneal projection absent. Corneas covered posteriorly by collar between supra- and extracorneal teeth. Pterygostomial corner projecting but rounded.

Antennular peduncle short and heavy, with second article almost twice as long as broad. Superior distal margins of first and second articles each armed with four strong teeth. Stylocerite narrow, with tip reaching to near end of second article. Upper flagellum with only trace of bifurcation. Antennal peduncle also heavy. Basicerite thick, lateral region projecting as a broad tooth, bearing broadly acute tip. Carpocerite very heavy, only 1.5 times as long as broad, and 1.3 times broader than thick; tip reaching beyond end of antennular peduncle. Scaphocerite with tip of lateral spine reaching slightly beyond end of antennular peduncle, squamous portion broad and rounded, almost as long as lateral spine. Antennal flagellum reaching posteriorly to end of second abdominal segment.

Mouth parts protruding as those in *A. paragracilis* Coutière and *A. huikau* Banner with inflated labrum and with psalistome of mandibles expanded and almost hemispherical; teeth on psalistome small and numerous.

Chelipeds symmetrical except for 10 per cent difference in size. Ischium heavy, 0.7 length of merus, bearing five to six movable spines on inferior, three on superior margin. Merus compressed, triangular in section, with inferior surface flat and less broad than sides; outer face 1.5 times as long as broad at maximum breadth. Carpus 0.8 as long as merus, proximally very thin and narrow, distally greatly expanded to be 0.5 as broad as long; triangular in section; distal margins slightly projecting to cover base of chela. Chela short, 1.8 times length of merus, flattened, with thickness 0.5 of maximum breadth; inner face flattened, outer face convex; suboval area of outer face running from base to articulation of flattened dactylus; area distally delimited on inferior side by rounded shoulder; triangular area of lower distal margin of palm and proximal portion of finger armed by strongly projecting papillae, those best developed longer than broad at base and turned distally; setae arising between bases of papillae; inner face without papillae. Dactylus 0.4 as long as palm, curved, crossing tips with fixed finger, armed with two low rounded teeth fitting exactly with cutting edge of fixed finger.

Second legs markedly shorter than third legs, with length from meral-carpal articulation equal to combined lengths of ischium and merus. First and fifth carpal articles subequal; second, third, fourth articles subequal, each about 0.4 length of first or fifth article; first carpal article proximally narrow, about half width of fifth article.

Third legs robust. Ischium unarmed, 0.5 length of merus. Merus unarmed, 0.4 as broad as long. Carpus armed distally on superior margin with rounded tooth, on inferior margin with subterminal movable spine; almost 0.6 as long as merus, slightly more than half as broad as merus. Propodus at most slightly longer than merus, slightly curved, with five inferior and one distal spines; spines leaving middle portion of propodus unarmed. Dactylus curved, acute, simple, bearing tuft of setae. Fourth legs similar but with spines of propodus more continuous in arrangement. Fifth legs with only three inferior spines on propodus; "brush" feebly de-

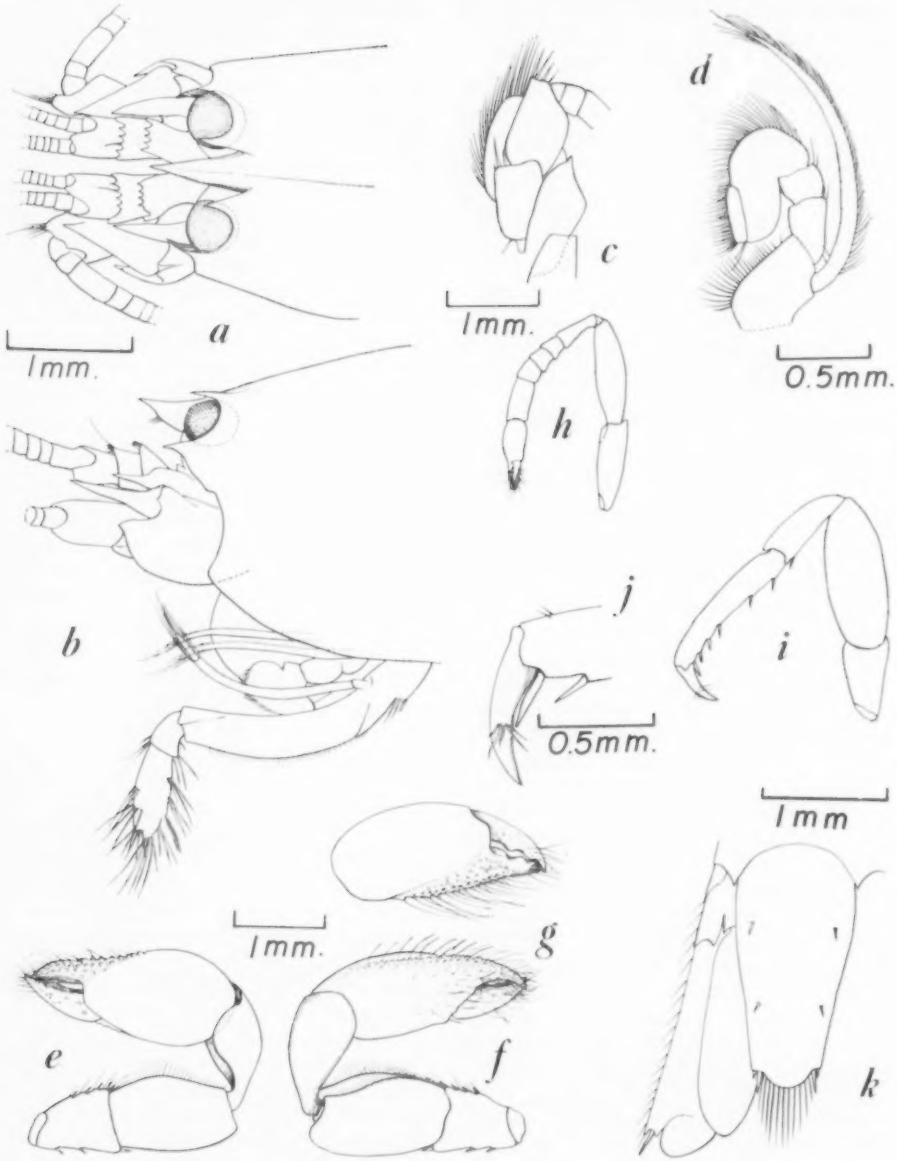


FIG. 4. *Athanas verrucosus* Banner. *a, b,* Anterior body region; *c,* antennal peduncle, inferior aspect, in situ; *d,* second maxilliped; *e,* smaller cheliped, lateral view; *f,* smaller cheliped, medial view; *g,* smaller chela, outer face, viewed flat; *h,* second legs; *i, j,* third leg and dactylus; *k,* telson and uropods.

veloped, with only three rows of light setae found distally.

Abdomen normal except anterior pleura greatly expanded, posterior pleura small; pleura of sixth segment articulated. Telson normal, sides almost straight, tapering, 2.2 times as broad anteriorly as posteriorly, 4 times as long as broad posteriorly; tip extended and rounded. Uropods normal, narrow and long.

Branchial formula including five pleurobranchs, no arthrobranchs, and mastigobranchs extending back to second thoracic leg, setobranchs to third. No anal tubercles.

DISCUSSION: In the old genus *Athanas* this species is closely related to none; in the old genus *Arete*, now united with *Athanas*, this species is most closely related to *A. borradailei* (Coutière, 1903: 9) and *A. ghardaqensis* (Ramadan, 1936: 15). From both of these species it is separated by the five-jointed carpus and the presence of papillae on the palm. The difference in the chelae could be from growth or sexual dimorphism. A point for point comparison reveals other more minor differences. This species differs from *A. ghardaqensis* by a greater number of articulations in the base of the inner flagellum, by the presence of a small tooth on the basicerite, and by longer uropods. From *A. borradailei*, this species is distinguished by: 1. A more sinuate lower margin of the rostrum and a triangular shape (when seen in dorsal view); 2. the presence of serrations on the distal ends of the antennular articles; 3. the presence of many articulations in the antennular flagellum; 4. slight differences in the last article of the external maxilliped; 5. on the chelipeds, the presence of spines on the ischium, and slight differences in the proportions of the merus and carpus in addition to the presence of papillae on the palm; 6. a broader merus of the third legs, being less than 2.5 times as long as broad instead of three times. Also *A. borradailei* is reported to lack all thoracic epipodites, while this species has masigobranchs on the base of the chela and second legs. Neither Coutière nor Ramadan discussed the mouthparts.

Each of these three species were described on the basis of a single individual. While the differences listed above, especially in the carpus of the second legs, the chelae and the branchial formulae may be valid for their separation, the three specimens are so similar in general configuration and in the structure of the appendages and rostral front that their specific separation is very doubtful, particularly in view of the variation in other species of this genus. However, with only one specimen of each nominal species, it appears to be safest to leave them as separate species.

The name *verrucosus* refers to the "warty" condition of the palm of the large chela, a character in which this species appears to differ from both related species.

Athanas indicus (Coutière)

Arete dorsalis var. *indicus* Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 85.

Arete indicus Coutière, 1905*b*. Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 863, figs. 134–135.

Arete iphianassa de Man, 1910*a*. Tijdschr. Ned. Dierk. Ver. II, 11(4): 312; 1911, Siboga Exped. 39a[1](2): 164, pls. 3, 4, fig. 11; 1922, Siboga Exped. 39a[4](5): 22, pl. 3, fig. 11.

——— Banner, 1956. Pacif. Sci. 10(3): 325.

Arete intermedius Yu, 1931. Bull. Mus. Hist. Nat., Paris II, 3(6): 513–514, fig. 1.

Arete kominatoensis Kubo, 1942. Dobutsugaku Zasshi [Zool. Mag., Tokyo] 54: 82–85, figs. 1, 2.

DISCUSSION: The habitat of 15 of 16 specimens from Aitutake was carefully observed while the collections were made. They came from the inner, but growing, portion of a windward reef, in a pool about six feet deep; every specimen was associated with the boring sea urchin, *Echinometra*, and were found both on the body of the urchin between the spines and within the smooth rounded cavity produced by the urchin. While most of the other specimens were not as carefully observed during their collection, the ones that were noted (as from Eniwetok) were so associated. Evidently, not all individual specimens of *Echinometra* have shrimp in association, for *Echinometra* was frequently encountered while collecting and the shrimp are quite uncommon in the collection.

For the following discussion of variation within the species, it was considered best to

study a single population thereby ruling out differences that might be caused by ecological or geographic races. For this reason the 15 specimens from Aitutake were studied intensively and those from other archipelagoes were used merely as supplements to the study.

Four species closely related to *A. indicus* have been described: *A. iphianassa* de Man, *A. amboinensis* de Man, *A. intermedius* Yu, and *A. kominatoensis* Kubo (all save the last described under the genus *Arete*). Of these, only *A. amboinensis* appears to be distinct; it will be discussed under *A. dorsalis* in the following section.

de Man stated that his species *A. iphianassa* was similar to *A. indicus*, but could be distinguished by the characteristics compared in the accompanying tabulation.

In this series of specimens each of the criteria is either bridged or almost bridged:

1. The length of the extracorneal spines varies both in absolute length and in length relative to the eyes; both described conditions were found in this single series.

2. The basal portion of the outer antennular flagellum is found to vary from four to six articles, with most having four or five articles.

3. The carpocerite is found to vary in the length-breadth relationship from 1:1.5 to 1:2.7; some of this may be due to different rotation of the carpocerite itself.

4. The outer distal margin of the outer uropod may be either straight or curved outward near the tip; all of the males have straight margins, but not all of the females have curved margins.

5. Similar to the condition discussed in the next section for *A. dorsalis*, the females and the smaller males have straight cutting edges of their large and small chelae; however, the two intact large males have teeth developed, one with a single tooth on the fixed finger, none on the dactylus, the other with two teeth on the fixed finger and one on the dactylus.

6. The proportions of the carpal articles of the second legs are extremely variable, with the first article varying from 1.4 to 3.0 times as long as broad distally; in some, also, the first article is approximately equal in length to the sum of the following carpal articles, in others it is almost twice as long.

7. The spines on the propodus of the third legs vary in number from four to nine, and also in development, with some scarcely more than slight hairs, and others strong and well developed.

Also like *A. dorsalis* the development of the rostrum varies conspicuously. In one specimen the tip reaches beyond the end of the third antennular article, in four it reaches some distance along the third article, in eight it reached somewhere in the length of the second article (most to near the tip of the article) and in one it reaches only to the end of the first article.

The other specimens in the collections available, including those reported from Saipan as *Arete iphianassa* (Banner, 1956: 325), fall within the range of variation reported above with the exception of three fragmentary specimens from Canton Island. These three, unfortunately mostly without legs and with but two chelae among them, all have slightly different

A. iphianassa	*A. indicus*
1. Extracorneal spines equal in length to the eyes.	1. Extracorneal spines slightly longer than the eyes.
2. Four articles on basal portions of outer antennular flagellum.	2. Six articles in same.
3. Carpocerite 1.5 times as long as broad.	3. Carpocerite 3.0 times as long as broad.
4. Outer distal margin of outer uropod straight.	4. Outer distal margin of outer uropod curved outward.
5. Various minor proportions of the large chelae, but principally with that of the male bearing 2 teeth on the dactylus and one on fixed finger.	5. Fixed finger of large chela of male bearing 1 tooth, dactylus curved but unarmed.
6. Various proportions in second leg, but most conspicuous in the first article of the carpus which is 5 times as long as broad distally.	6. First carpal article 3 times as long as broad distally.
7. Propodus of third legs bearing 8 to 12 spines.	7. Propodus of third legs bearing two to three spines.

rostrums: while its tip reaches to near the end of the second antennular article, well within the range specified above, it was considerably broader and thicker. Possibly more important, however, is the fact that the stylocerite also reaches only to the end of the second antennular article, instead of to the end of the third, a condition found in no other specimens. It may well be that these represent a new species or geographic or ecological subspecies, but with only three specimens, all in very bad condition, it is impossible to decide with certainty.

The other two nominal species also fall well within the range of variation. *A. intermedius* was separated by Yu from *A. indicus* by a slightly longer rostrum, reaching to one-quarter of the length of the third antennular article, and by the presence of 12 spinules on the propodus of the third leg. As shown in the listing above, both of these characteristics are very variable, and the separation of *A. intermedius* seems without basis.

There is more doubt about the combination of *A. kominatoensis* with this species. Unfortunately Kubo did not contrast his species to *Arete*, where it belonged under the old classification (it has only four articles in the carpus of the second leg) but to *Athanas*. By contrasting the description and figures of Kubo with *A. indicus* the three differences are found: 1. The antennular peduncle is 2.2 times as long as broad instead of 3.0 (using the entire visible length of the peduncle divided by the breadth of the second article). 2. Kubo reports and shows a slight dorsal carina extending back to the middle of the carapace, while in *A. indicus* there is no true carina but rather a broad ridge terminating slightly behind the eyes. 3. The inferior margin of the merus of the third legs bears distally a slight tooth while in *A. indicus* it bears a strong tooth. It may be that these are valid criteria, especially the porportions of the antennular peduncle and dorsal carina—the development of the tooth on the third leg has been shown to be variable in the related *A. dorsalis*—and none of the specimens available closely approach the condition described by Kubo. However, in view of the wide variation already reported in this species and in *A. dorsalis* these seem to be questionable characteristics for a specific separation, yet it may be this form, being found as it is in the waters of southern Japan, is a separate subspecies.

DISTRIBUTION: This species has been reported from Djibouti, Maldives and Laccadives, Indonesia, China, and southern Japan. In the present collection we have specimens from Canton, Aitutake, Bora Bora, and the northern Marshall Islands. They were found in heads of dead coral and associated with the boring sea urchin *Echinometra*.

Athanas dorsalis (Stimpson)
Figs. 5, 6

Arete dorsalis Stimpson, 1861. Proc. Acad. Nat. Sci. Philad. 12: 32.

(?) *Athanas mascarinicus* Richters, 1880. Beitr. Meeresfauna der Insel Mauritius und der Seychellen, Decapoda, p. 164.

Arete dorsalis var. *pacificus* Coutière, 1903. Bull. Soc. Philom. Paris IX, 5(2): 87, figs. 31–34.

Arete maruteensis Coutière, 1905*a*. Bull. Mus. Hist. Nat., Paris 11(1): 19, figs. 1–6.

Arete maruteensis var. *salibabuensis* de Man, 1910*a*. Tijdschr. Ned. Dierk. Ver. II, 11(4): 313; 1911, Siboga Exped. 39a^1(2): 169, pl. 4, fig. 13.

DISCUSSION: To determine the validity of the separation of the three species and subspecies listed above, the specimens in the collection, especially a single collection of about 50 from Namu Island, Marshalls (Station 3167, J. E. P. Morrison), were examined closely. Of these specimens from a single locality, about 30 intact specimens were measured, and the findings confirmed by examination of the specimens from other parts of the Pacific.

Rostrum: In general the form of the rostrum is anteriorly a sharp triangle with an acute tip, while between the eyes the sides approach a parallel condition. In most the tip of the rostrum reaches to the end of the first antennular article or to the first half of the second article; in three specimens it reaches well into the second half of this article, and in one it reaches the beginning of the third article. In most cases it is between 1.6 to 2.1 times as long as broad.

Extracorneal Teeth: In most these are well developed, but to varying degree, and there is

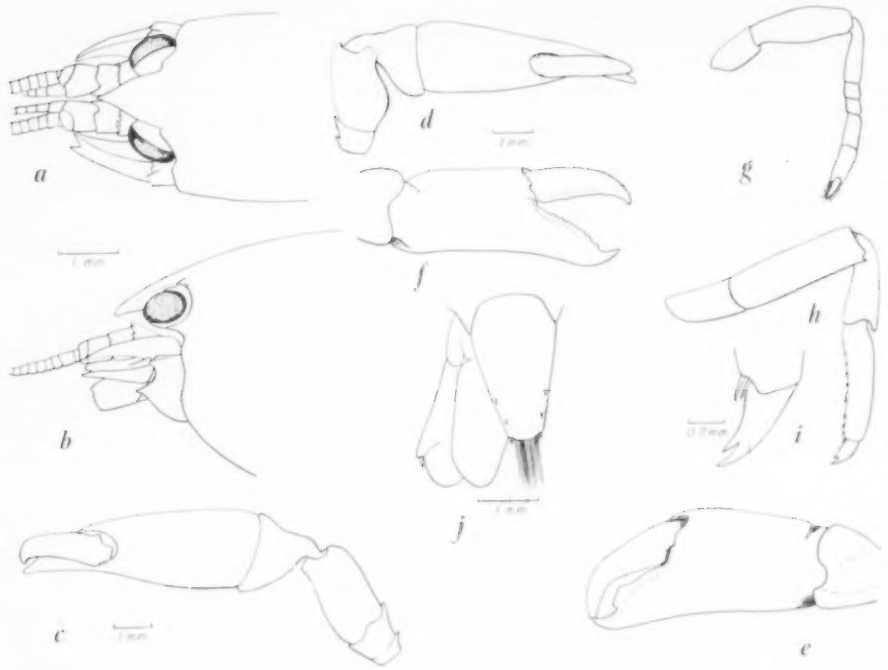


FIG. 5. *Athanas dorsalis* (Stimpson), a 5.5 mm. (carapace length) ovigerous female from Raroia, Tuamotus, Station 1847. *a, b.* Anterior region, dorsal and lateral aspects; *c, d.* large and small chelae, lateral view; *e, f.* same, from lower side; *g.* second leg; *h.* third leg; *i.* third leg, dactylus; *j.* telson and uropod.

a gradual series from those with pronounced teeth to the few with very slight teeth and to the one specimen (from the Tuamotus) without any teeth.

Antennular and Antennal Peduncles: Usually the stylocerite reaches to near the end of the antennular peduncle, the scaphocerite and carpocerite exceeding the stylocerite slightly; in no case are the differences in length pronounced, and at times the relationships change.

Large Chela: This appendage is found to exhibit strong growth and sexual differences (see Fig. 6*a–f*), with the young of both sexes showing a more or less uniform taper to the fingers which bear minute serrations on the basal two-thirds and the distal third being smoothly rounded to the curved tip. In adult females there is commonly an outgrowth of an irregular lobe proximal to the distal curve on the larger chela, while the other chela remains more like that found in the young. In some of the largest males the large chela has developed an exceedingly large tooth on the fixed finger, against which the dactylus closes; however, in other large males and in all smaller males this tooth is variously developed and much smaller. In both sexes the development of the chelae varies considerably between individuals of the same size, and in one very large ovigerous female the tooth of the fixed finger is as fully developed as that of the large male.

Small Chela: In most specimens, male and female, the cutting edge of the finger bears numerous low irregularities which stop abruptly in a tooth that may be obtuse or a right angle. The distal portion is curved. However, in some the irregularities are considerably smoothed, and the final tooth may be low and rounded.

Second Legs: In the merus the length-breadth ratio varies from 1:2.5 to 1:3.7, with most of the specimens bearing the ratio between 1:2.8 to 3.0. Only in a small series the relative lengths of the carpal articles and hand were measured, and these show that the extent of variation is similar to that of the merus.

Third Legs: Three characteristics of the third legs have been carefully observed: the length-breadth ratio of the merus varies from 1:2.5 to 1:3.4, with most of the specimens with the ratio between 1:2.9 to 3.1. The final outer tooth of the inferior margin in no specimen is large and no specimen is lacking, with the maximal development being about that shown in Figure 5*b*, while in the minimal development the tooth is barely visible, and is scarcely more than an obtuse irregularity; it also varies from slightly acute to obtuse. The length-breadth ratio of the propodus exhibits less variation than do the other measured articles, ranging from 1:4.0 to 1:4.6, with most of the specimens grouping around 1:4.5.

Telson: In all of the specimens except three the telson is found to be 3.2 to 4.0 times as long as the posterior margin is broad, with most 3.2 to 3.3 times. In two specimens the telson is only 3.0 times as long as broad, and in one it is 4.2 times as long.

The extent of this variation destroys the validity of the separation of *A. maruteensis* and *A. dorsalis*. Coutière separated his species (which he originally called *A. dorsalis pacificus*) upon the following characteristics: 1. shape of rostrum; 2. traces of extracorneal spines; 3. shape and armature of large and small chelae; 4. relative proportions of the carpal articles and chelae of second legs (for this character it should be noted that in the specimens measured some would be like *A. dorsalis* in two of the relative measurements and like *A. maruteensis* in the third); 5. the length-breadth relation of the articles of the third leg, and the presence of a definite tooth on the merus as opposed to being "coupè â angle droit" in *A. maruteensis*. To these differences de Man adds, in his separation of the subspecies *A. maruteensis salibabuensis* the proportions of the rostrum and merus of the second and third legs. In the group of specimens measured each of the characteristics was found to be

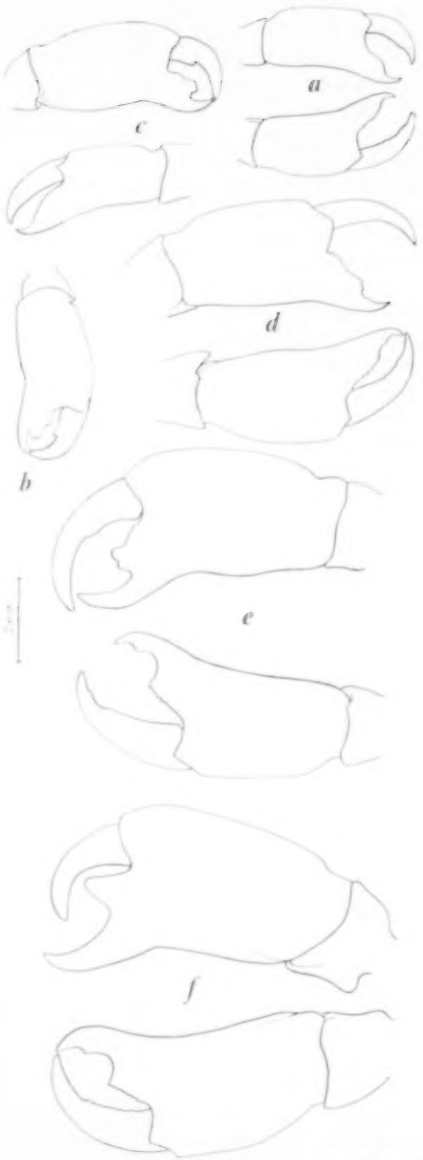


FIG. 6. *Athanas dorsalis* (Stimpson), variations in the development of the chelae. *a*, Male of 3.3 mm. carapace length; *b*, male of 3.5 mm. carapace length; *c*, male of 3.85 mm. carapace length; *d*, male of 4.95 mm. carapace length; *e*, male of 4.95 mm. carapace length; *f*, male of 5.2 mm. carapace length. All drawn to same scale.

variable, with the range of variation not only bridging the supposed differences between the nominal species and subspecies, but also extending beyond any previously reported condition. It is interesting to note that the specimens that agreed best with *A. dorsalis* were those from Raroia, not too far from the type locality of *A. maruteensis,* while the specimens from the Marshalls were more like the description of *A. maruteensis.*

The exact status of *A. mascarinicus* Richters is not known, as the description, without figures, is inadequate. It may be a synonym of this species; it may be the same as, and take priority over *A. indicus* or *A. amboinensis;* it may be regarded as a *nomen dubium;* or it may be a separate and valid species. Unless the type specimen can be redescribed, we feel it is safest to consider it as a synonym of *A. dorsalis.*

On many of these specimens, including the large group from the Marshalls, it was specified that they were collected from large sea urchins of the genus *Heterocentrotus;* however, for some their habitat was specified as "coral" (as was that of Stimpson's original specimen). Whether this indicates that the species normally lives only on sea urchins but may desert them if the urchin is disturbed, as by a collector, or whether it indicates that the species may live either on coral or sea urchins is not known. At least, no significant differences were found between those collected from urchins and those collected from unspecified "coral."

Athanas amboinensis (de Man, 1910*b*: 25–27, figs. 1–6) is, at least, closely related to *A. dorsalis,* more closely than *A. indicus* (Coutière); it may be found to be a synonym. However, as none of the specimens in the collection approach the proportions of the slender chela and narrow telson given by de Man as specific characteristics, there is no evidence that the two should be combined.

DISTRIBUTION: Stimpson's original specimens came from Hongkong and it has been reported from Djibouti, Indian Ocean, Indonesia, New Caledonia, Kermadec Islands and Samoa. In the present collection we have about 70 specimens, the majority from the Marshall Islands, 2 specimens from Canton Island, 1 from Fiji and 6 from the Tuamotus. At least 50 of the specimens were commensal with the sea urchin *Heterocentrotus.*

REFERENCES

BALSS, HEINRICH. 1915. Die Decapoden des Roten Meeres: Macruren Expeditionen S. M. Schiff "Pola" in das Rote Meer. Ergebn. Zool. 30: 1–38, 30 figs.

BANNER, ALBERT H. 1956. Contributions to the knowledge of the Alpheid shrimp of the Pacific. I. Collections from the Mariana Archipelago. Pacif. Sci. 10(3): 318–373, figs. 1–23.

BARNARD, K. H. 1950. Descriptive Catalogue of South African Decapod Crustacea. Ann. S. Afr. Mus. 38. 837 pp., 154 figs.

BORRADAILE, L. A. 1898. On some crustaceans from the South Pacific. Part III. Macrura. Proc. Zool. Soc. Lond. 1898: 1000–1015, pls. 63–65.

CHACE, FENNER A., JR. 1955. Notes on shrimps from the Marshall Islands. Proc. U. S. Natl. Mus. 105(3349): 1–22.

COUTIÈRE, H. 1897. Note sur quelques alphéidés nouveaus ou peu connus rapportes de Djibouti. Bull. Mus. Hist. Nat., Paris 3(6): 233–236.

——— 1899. Les "Alpheidae," Morphologie, externe et interne, formes larvaires, bionomie. Thèses présentées à la Faculté des Sciences de Paris. . . Sér. A, No. 321 [no. d'Ordre 980]. 599 pp., 409 text figs., 6 pls. Masson et Cie, Paris. [Also: Ann. Sci. Nat. VIII, Zool. 9: 1–560.]

——— 1903. Note sur quelques Alpheidae des Maldives et Laquedives. Bull. Soc. Philom. Paris IX, 5(2): 72–90.

——— 1904. Note sur le commensalisme de l'*Arete dorsalis* var. *pacificus* Coutière, d'après les notes de M. L. Seurat, naturaliste, à Rikitea (Îles Gambier). Bull. Mus. Hist. Nat., Paris 10(2): 58–60.

——— 1905*a*. Note sur quelques Alpheidae recueilles par M. G. Seurat à Marutea (Îles Gambier). Bull. Mus. Hist. Nat., Paris 11 (1): 18–23.

——— 1905*b*. Marine Crustacea, XV. Les Alpheidae. IN: Fauna and Geography of the Maldive and Laccadive Archipelagoes [J.

Stanley Gardiner, ed.] vol. 2, part 4, pp. 852–921, pls. 70–87, figs. 127–139.

——— 1908. Sur quelques nouvelles espèces d'Alpheidae. Bull. Soc. Philom. Paris IX, 11(5): 1–26.

DE MAN, JOHANNES GOVERTUS. 1910*a*. Diagnoses of new species of macrurous decapod Crustacea from the "Siboga Expedition." Tijdschr. Ned. Dierk. Ver. II, 11(5): 287–319.

——— 1910*b*. Ueber eine neue art der gattung *Arete* Stimpson. Arch. Naturgesch. 76(1): 25–27, figs. 1–6.

——— 1911. The Decapoda of the Siboga Expedition. Part II. Family Alpheidae. IN: Siboga Expeditie 39a¹(2): 133–465 [Livre 60]; 1915, supplement [plates and explanations] 39a¹(2): 23 pls. [Livre 74].

——— 1922. The Decapoda of the Siboga Expedition. On a collection of macrurous decapod Crustacea of the Siboga Expedition, chiefly Penaeidae and Alpheidae. IN: Siboga Expeditie 39a⁴(5): 1–51, pls. 1–4 [Livre 93].

KEMP, STANLEY. 1915. Fauna of the Chilka Lake, Crustacea Decapoda. Mem. Indian Mus. 5(3): 199–326.

KUBO, ITUO. 1940*a*. On some littoral shrimps collected from Micronesia. J. Fish. Inst. Tokyo 34(1): 77–99, figs. 1–15.

——— 1940*b*. Notes on the Japanese Shrimps of the genus *Athanas* with a description of one new species. Annot. Zool. Jap. 19(2): 99–106, 5 figs.

——— 1942. On a snapping shrimp, *Athanas kominatoensis*. Dobutsugaku Zasshi [Zool. Mag., Tokyo] 54: 82–85, figs. 1, 2.

LEACH, W. E. 1814. Crustaceology. IN: Edinb. Encyc. 7: 383–437, pl. 221. (D. Brewster, ed.)

RAMADAN, M. M. 1936. Report on a collection of Stomatopoda and Decapoda from Ghardaqa, Red Sea. Bull. Fac. Sci. Egypt. Univ. (6): 1–43, pls. 1–2.

RICHTERS, F. 1880. Crustacea Decapoda of Mauritius and Seychelles. IN: Beiträge zur Meeresfauna der Insel Mauritius und der Seychellen, Decapoda. [K. Mobius, ed.] vi +352 pp., 25 pls. Gutmann, Berlin.

STIMPSON, W. 1861. Prodomus descriptionis animalium evertebratorum, quae in expeditione ad Oceanum Pacificum Septrentrionalem ... Par. VIII. Crustacea Macrura. Proc. Acad. Nat. Sci. Philad. 12: 22–47. [Proc. for 1860.]

YU, SHOU-CHIE. 1931. Description de deux nouvelles crevettes de Chine. Bull. Mus. Hist. Nat., Paris 3(6): 513–516.

Charadracarus new genus, Charadracarinae new subfamily (Acari, Johnstonianidae), and the Status of *Typhlothrombium* Berlese 1910

IRWIN M. NEWELL[1]

BERLESE AND LEONARDI (1901: 17) described a mite from Argentina which they named *Trombidium histricinum*. The species was described as follows: Dark cinnabar, large, broad-shouldered, flattened dorsally, rounded posteriorly. Body setae 25 μ long, sharp, spiniform, cinnabar, dense. Cephalothorax nude, except in median portion. Crista metopica linear, a tubercular elevation posteriorly, containing the areolae. Palpal tarsus long, clavate, extending beyond the claw; tibia with an ornate series of six spines along the internal surface, a single terminal claw. Legs rather long, setae plumose, irregularly ornate. Tarsus I at least five times longer than broad. I was unable to see eyes by any means. Adult 3 mm. long. One specimen collected at St. Pedro Mission, Argentina. (Author's translation.) No figures were given.

Berlese (1910: 358) designated *Trombidium histricinum* as type species of the new genus *Typhlothrombium*. The original description of the genus was very brief, including little beyond the original description of the type species, except for the fact that a nasus was present. Characteristics set forth in the original description of the genotype which are at variance with descriptions of the two species subsequently placed in this genus (*Typhlothrombium grandjeani* André 1930, *Typhlothrombium aelleni* Cooreman 1954) are: the dark red color, flattened dorsum, the very short setae (25 μ), the denseness of the chaetotaxy, the presence of a well-developed ctenidium, the slender form of tarsi I, and the large size of the body (3 mm.). The differences are so considerable as to leave no doubt that *Typhlothrombium grandjeani* and *Typhlothrombium aelleni* have nothing to do, at the generic level, with *Typhlothrombium histricinum*. The only unusual feature pointed out up to this time which is shared by *Typhlothrombium histricinum* on the one hand and *T. grandjeani* and *T. aelleni* on the other hand is the absence of the eyes. This is not a very significant point of similarity, however, in light of the many points of difference noted above. The genus *Typhlothrombium* Berlese 1910 therefore must be restricted to the type species. The family status of *Typhlothrombium* is uncertain, but it is provisionally retained in the Trombidiidae.

The author has had the opportunity of studying a form very similar to *Typhlothrombium grandjeani* André, which occurs in southern California. A second North American species, from Point Barrow, Alaska, has been collected by Dr. Paul Hurd of the University of California at Berkeley. Finally, through the courtesy of Dr. Marc André, I have been able to study type material of *Typhlothrombium grandjeani*. These three species, together with *Typhlothrombium aelleni* Cooreman comprise a natural group of congeners, *Charadracarus* new genus, with *C. hurdi* new species as the genotype.

The genus is unusual in several important respects although it is obviously closely related to the Johnstonianidae. While there are important points of difference between the species of *Charadracarus* and other members of the Johnstonianidae, it appears that these differences can be suitably recognized by establishing a new subfamily within the Johnstonianidae.

ACKNOWLEDGMENTS

This study was carried out under a research grant (NSF G-4251) from the National Science Foundation to the University of California at Riverside. The illustrations are by Mari Riess of the University of California at Riverside. In the figures, the scales are marked in 10 μ units.

[1] University of California, Riverside, California.
Manuscript received March 17, 1959.

CHARADRACARINAE new subfamily

Since the genus *Charadracarus* is the only one known at the present time, the characteristics of the subfamily are the same as those of the genus. The most significant characters which separate the *Charadracarinae* from the other subfamilies of the Johnstonianidae are: (1) the presence of only two pairs of genital acetabula in the adult, (2) the single pair of genital sclerites (the paragenitals apparently being absent), (3) the absence of tracheae in both larvae and adult, (4) the undivided femur in legs III and IV of the adult and in leg III of the larva. The absence of corneae and ocular plates is important, but the same condition has been reported in *Crossothrombium parkhousei* Womersley 1939, as well as in *Typhlothrombium histricinum* (Berlese and Leonardi) 1901.

The habits are not well known. The larvae are almost certainly of the self-detaching type and may be simple predators on small soil organisms. The predatory nature of the larvae is surmised from the fact that they have never been found on a host, in combination with the fact that they show a great variation in size in the soil, indicating that they are feeding and growing. The larvae are almost colorless and adults are pale yellow to white—not dark brown or red like other Johnstonianidae. The writer has found them in large numbers in the winter under black oak (*Quercus kelloggii* Newberry) in the mountain ranges of southern California. This oak usually grows in situations where soil moisture is more abundant than in other places, either in deep gullies or on north slopes, etc. Thus, while *Charadracarus* deviates more than other known Johnstonianidae from a subaquatic habitat, their ecological distribution is still relatively restricted. At the type locality of *C. delitescens,* hundreds of individuals were found under the oaks on the south side of a gully, but the species was totally absent from the northern side of the gully where only the coast live oak (*Quercus agrifolia* Neé) was found.

CHARADRACARUS new genus

ADULTS: Idiosoma rather small, less than 1 mm. in length; color pale yellow to white. Scutum with sensilla bearing a bulblike expansion in known forms; prosensilla more than one half as long as the sensilla, but markedly different from the sensilla, more closely resembling the other setae of the scutum. Anterior end of scutum drawn out into a long sharp spine closely appressed to the dorsal wall of the propodosoma. Dorsum of gnathosoma without spiracular openings. No major tracheal trunks associated with cheliceral apodemes internally. Dorsum of propodosoma with no setae lateral to scutum. Corneae and eyes absent. Chaetotaxy of hysterosoma simple, setae only a little more numerous than in the larva. Genital opening bordered by only one pair of sclerites; paragenital sclerites absent. Two pairs of genital acetabula in both sexes. Pregenital tubercle absent. Anus lying in the completely undifferentiated ventral cuticle between the genital opening and the posterior end of the body; no trace of anal sclerites or anal setae. Anterior wall of trochanter of palp with no trace of a fenestra. Palpal tibia with or, usually, without paradont. Solenidion of palpal tarsus basal in position. Eupathidia confined to tarsi I and II, absent from tarsi III and IV and all other segments of the legs. Supracoxal setae absent from gnathosoma and coxa I; vestigial setae also completely absent. Solenidia$_1$ and s_2 only moderately differentiated but s_2 distinctly shorter and straighter than s_1. s_3 and s_4 convergent in form, s_4 only a little heavier and with a little more distinct internal structure in typical cases, but intermediate forms exist which are unassignable to either category.

LARVA: Scutum with four pairs of setae, the prosensilla more like the other setae of the scutum than like the sensilla. Nasus sharp, closely appressed to the dorsal surface of the propodosoma. Crista metopica feebly developed, confined to the portion of the scutum behind the areae sensilligerae. Ocular plates absent. Coxal setae numbering 2–1–2. Urstigma present and well developed. A number of setae in the membranous cuticle between coxae II and III. Anal sclerites absent. Deutorostral setae apparently absent, rostrum with only the proto- and tritorostrals. Anterior wall of palpal trochanter not fenestrated. Terminal setae of palpal tarsus not typically eupathidiform, but flattened and heavy walled. Tarsal eupathidia numbering

2–1–0, e_1 of tarsus I with basal companion seta. S_4 of tibia I without companion seta. Supracoxal setae absent on gnathosoma and coxa I; vestigial setae absent from patella and tibia of all legs. Femora I and II divided, six free segments beyond the coxa; III undivided, only five free segments beyond the coxa. All tarsi with two nearly equal claws, the posterior ones a little larger and more erect than the anterior ones. Intercoxal area with more than one pair of setae between coxae II and III.

REMARKS: The genus is remarkable for the way in which the larval characters have, in many cases, been carried over into the adult with little change. The general body form is strikingly similar in both stages, and the chaetotaxy of the body is nearly as simple in the adult as it is in the larva. Perhaps the greatest similarity in the two instars is in the structure and chaetotaxy of the appendages. In the larva of *C. delitescens,* the chaetotaxy of the palpal tarsus is very reminiscent of that found in *Johnstoniana, Diplothrombium,* and *Centrotrombidium,* being virtually identical with the latter. In these three genera, however, the two or more dorsal and distal setae of the tarsus (which evidently are modified eupathidia) are replaced in the adult by typical eupathidiform setae. In *Charadracarus delitescens,* on the other hand, these setae are easily recognizable in the adult and have almost precisely the same form that they had in the larva. The total number of setae on the palp of the adult is increased only a little over that of the larva, and there is usually (exception: *C. aelleni*) no development of the paradont on the palpal tibia such as occurs in all the other genera of the Johnstonianidae.

The femur, which is undivided in leg III of the larva remains undivided in the adult, too, and femur IV also has no trace of a subdivision. In both larva and adult, the eupathidia are confined to tarsi I and II; moreover there is no proliferation whatever of the eupathidia on tarsus II, there being a single eupathid in both larva and adult. There is an appreciable increase in the number of eupathidia on tarsus I. There is a single solenidion$_1$ on tarsus I of the adult just as in the larva, whereas in other genera there is often an increase in the number of s_1 in the transition from larva to adult (*Centrotrombidium, Johnstoniana*). In all these characteristics, the members of the genus appear to be highly neotenic. The presence of numerous setae in the intercoxal area of the larva is, on the contrary, a typically postlarval characteristic.

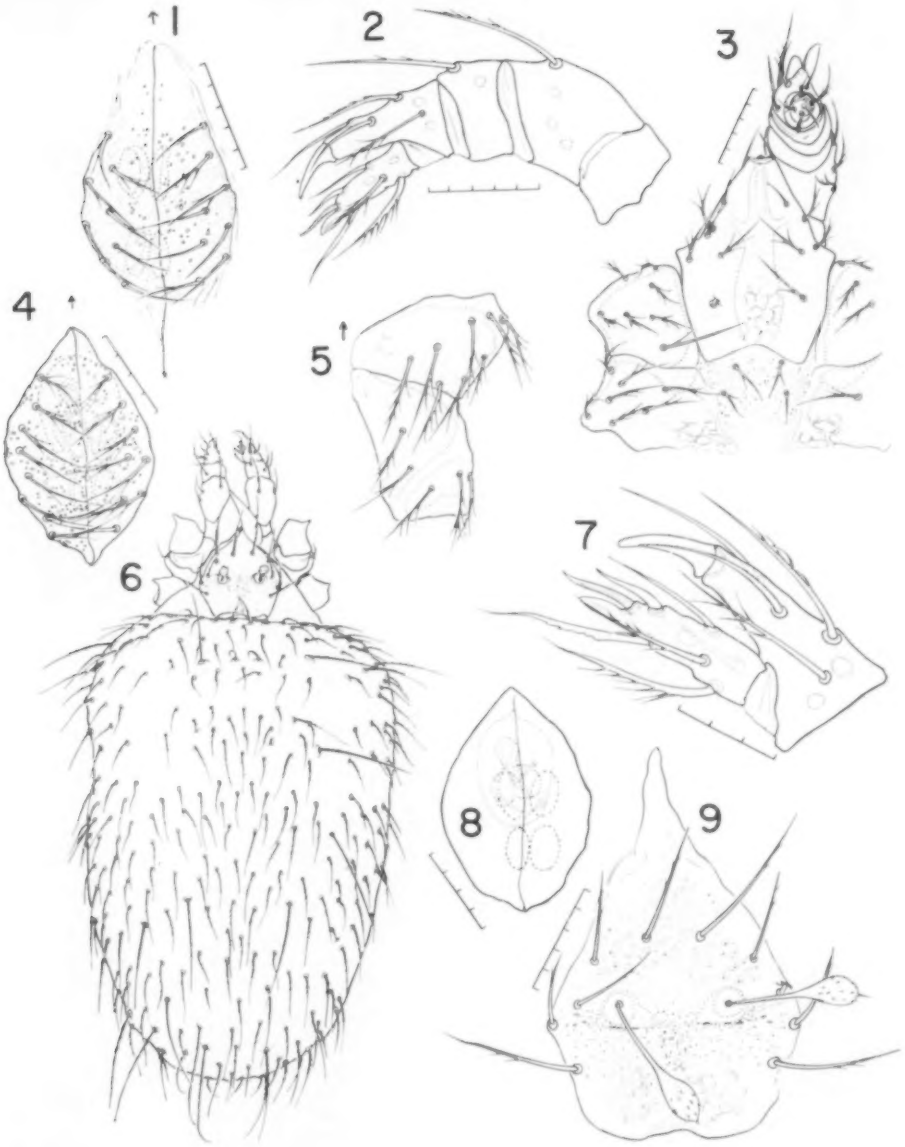
TYPE SPECIES: *Charadracarus hurdi* new species.

CHARACTERS SHOWING INTERSPECIFIC VARIATION IN THE GENUS CHARADRACARUS

The known species of this genus show a high degree of homogeneity in structure. The observed differences, in many cases, are so minor that the possibility of environmental influences can not be dismissed. However, until the existence of such influences have been proved experimentally, we must assume that the observed differences have actual specific value. The structures exhibiting variants of specific value are discussed here briefly, and are then summarized in a formula key.

Sensilla. At least two types of sensilla occur in the genus. In all known species but *C. hurdi,* the sensilla are fusiform, with a club-shaped swollen portion at the end of a long slender stalk, and beyond this the shaft of the seta tapers to a fine point. The portion of the shaft proximal to the swelling is nearly the same length as the portion distal to the swelling. In *C. hurdi,* the distal portion is almost completely wanting; an indication of it is seen only at high magnification (Fig. 9). In both types, the swollen portion of the sensillum bears a number of fine points.

Setae of Hysterosoma. In the adults of all described species, there are two series of setae, major and minor, the minor setae being smaller and much more numerous than the major. Cooreman (1954: 14–17) indicated that there are six pairs of major setae in *C. aelleni.* The number and arrangement in the three species studied by the writer are not especially regular. The distinct interspecific differences are found, however, in the form of the major setae. In *C. hurdi* and *C. aelleni,* the major setae are like the minor in the filiform tips. In the remaining two species, on the other hand, the tips of the major setae are distinctly swollen and bear a tuft of fine barbs. The terminal tuft of barbs in



FIGS. 1–9. *Charadracarus hurdi*, n. sp., adult: 1, genital area, female; 2, right palp, anterior, female; 3, prosoma, female; 4, genital area, male; 5, left coxae III and IV, female; 6, dorsum, male (same scale as Fig. 31); 7, tibia and tarsus of palp, anterior, female; 8, genital area, male, with external detail omitted; 9, scutum, female.

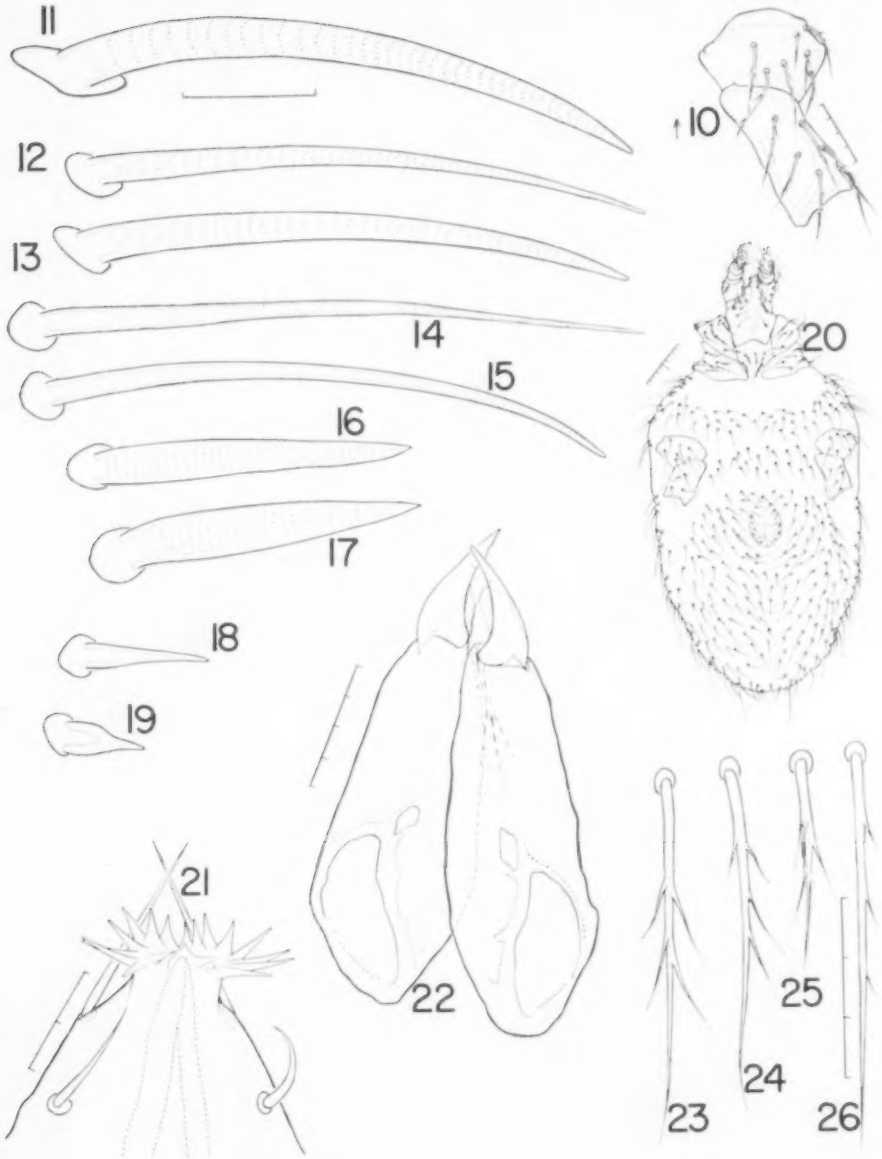
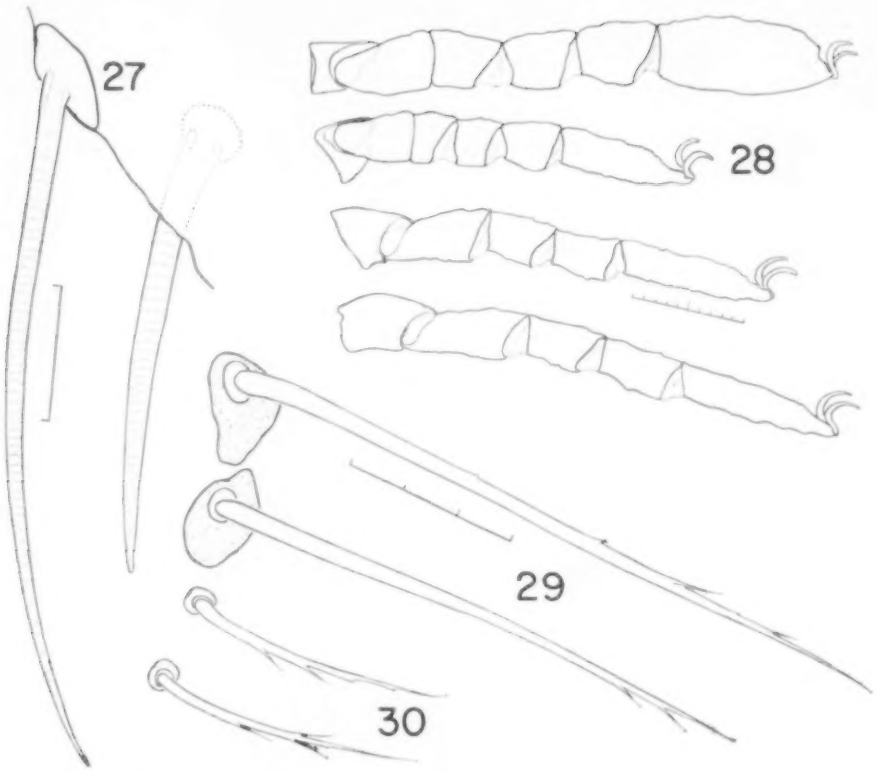


FIG. 10. *Charadracarus delitescens*, n. sp.: coxae III and IV, female.

FIGS. 11–26. *Charadracarus hurdi*, n. sp., adult: 11, s_1, tarsus I; 12, s_4, tarsus I; 13, s_4, tibia I; 14, s_5, tibia I; 15, s_3, telofemur I; 16, s_2, tarsus I; 17, s_2, tarsus II; 18, f_1, tarsus I; 19, f_2, tarsus II; 20, venter, male; 21, tip of rostrum, ventral, male; 22, chelicerae, semi-ventral; 23, seta, coxa II; 24, seta, coxa IV; 25, 26, ventral body setae. (Figs. 23–26 drawn from female.)

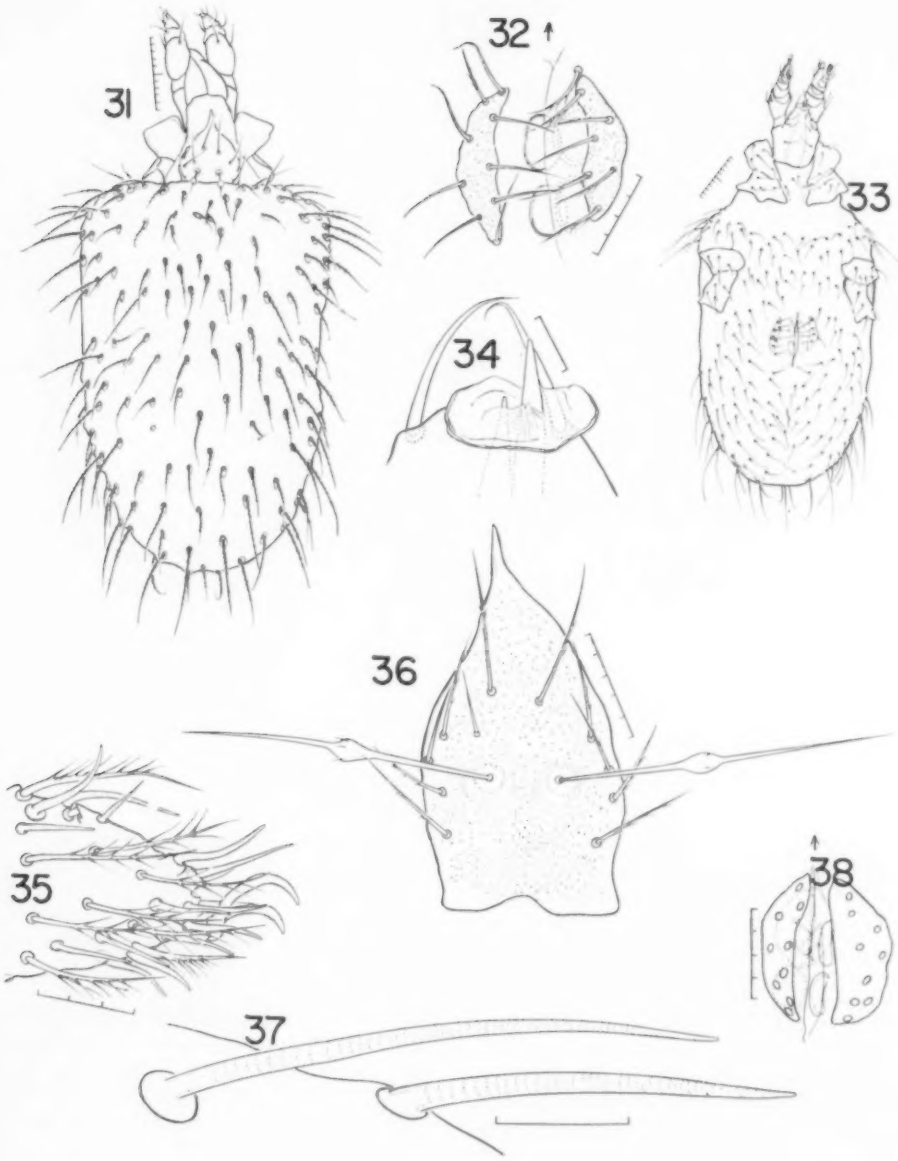


FIGS. 27–30. *Charadracarus hurdi*, n. sp., adult: 27, dorsal solenidia of tibia IV; 28, outline drawings of legs I-IV, female; 29, major body setae, female; 30, minor body setae, female.

C. delitescens and *C. grandjeani* has no counterpart in the other two species (cf. Figs. 29 and 45). The terminal portion of the major setae of *C. delitescens* and *C. grandjeani* is cavitated. The number and arrangement of the dorsal hysterosomal setae also show some differences, although these are not as easy to utilize in differentiating between species as are some of the other characters (compare Figs. 6 and 31).

Eupathidia of Palpal Tarsus. In the adult of *C. hurdi*, the most distal of the two distidorsal setae has a hollow shaft and is typically eupathidiform in structure. Its more basal counterpart is solid, except for a very slight and almost unnoticeable basal excavation. In adults of *C. delitescens*, both of these setae are solid. In the larva of *C. delitescens* (Fig. 72) the terminal eupathid is canaliculate in the basal portion, but this condition does not persist in the adult, at least in the specimens examined by the writer. The situation in *C. aelleni* is unknown, but in the type of *C. grandjeani*, the distal one is hollow, as in the case of *C. hurdi*.

Paradont of Palpal Tibia. In his original description of *C. aelleni*, Cooreman showed a distinct and well-formed paradont at the base of the terminal odontus of the palpal tibia. None of the other three species of the genus has such a seta in this position. It would appear that the paradont is not an additional seta in the case of *C. aelleni*, for the setae of the tibia of that species are the same in number as in the other three species of the genus. The only difference appears to be that one of the normal setae in



FIGS. 31–38. *Charadracarus delitescens*, n. sp., adult: 31, dorsum, female; 32, genital area, female; 33, venter, female; 34, tip of rostrum, female; 35, end of tarsus I, posterior, female; 36, scutum, female; 37, solenidia of tibia IV, female; 38, genital area, male.

C. aelleni has moved distally and become modified in form and size.

Structure of Rostrum. An interesting feature in the structure of the tip of the rostrum is found in *C. hurdi* and *C. delitescens.* This is a sexual difference, and not an interspecific one. In the females, the tip of the rostrum is simple, the velum being a flattened and fairly regular disc (Fig. 34). In the males of both species, however, the velum is rather elaborately drawn out around the margins into a number of fine points (Fig. 21).

FORMULA KEY TO SPECIES OF CHARADRACARUS

Based on Adults

1a. Sensilla fusiform, greatly swollen near middle, the tapering distal portion of the sensillum as long as or nearly as long as the basal portion (Fig. 36).

1b. Sensilla essentially clavate, filiform distal portion greatly reduced or absent (Fig. 9).

2a. Major setae of hysterosoma tapering to a fine point, no terminal tuft of barbs (Fig. 29).

2b. Virtually all major setae of hysterosoma with distal end inflated, hollow, and with a tuft of fine barbs (Fig. 45).

3a. Tarsus of palp with terminal seta eupathidiform, hollow throughout most of length (Fig. 7).

3b. This seta solid throughout virtually the entire length of the shaft, not eupathidiform (Fig. 48).

4a. Tibia of palp with a terminal odontus plus six slender, tapering normal setae; paradont absent (Figs. 7; 44).

4b. Tibia of palp with a terminal odontus and a paradont (Cooreman, 1954: 17, fig. 8).

5. Length of idiosoma, to tip of nasus, by sex.

NOTES ON MORPHOLOGY AND TERMINOLOGY IN THE PARASITENGONA

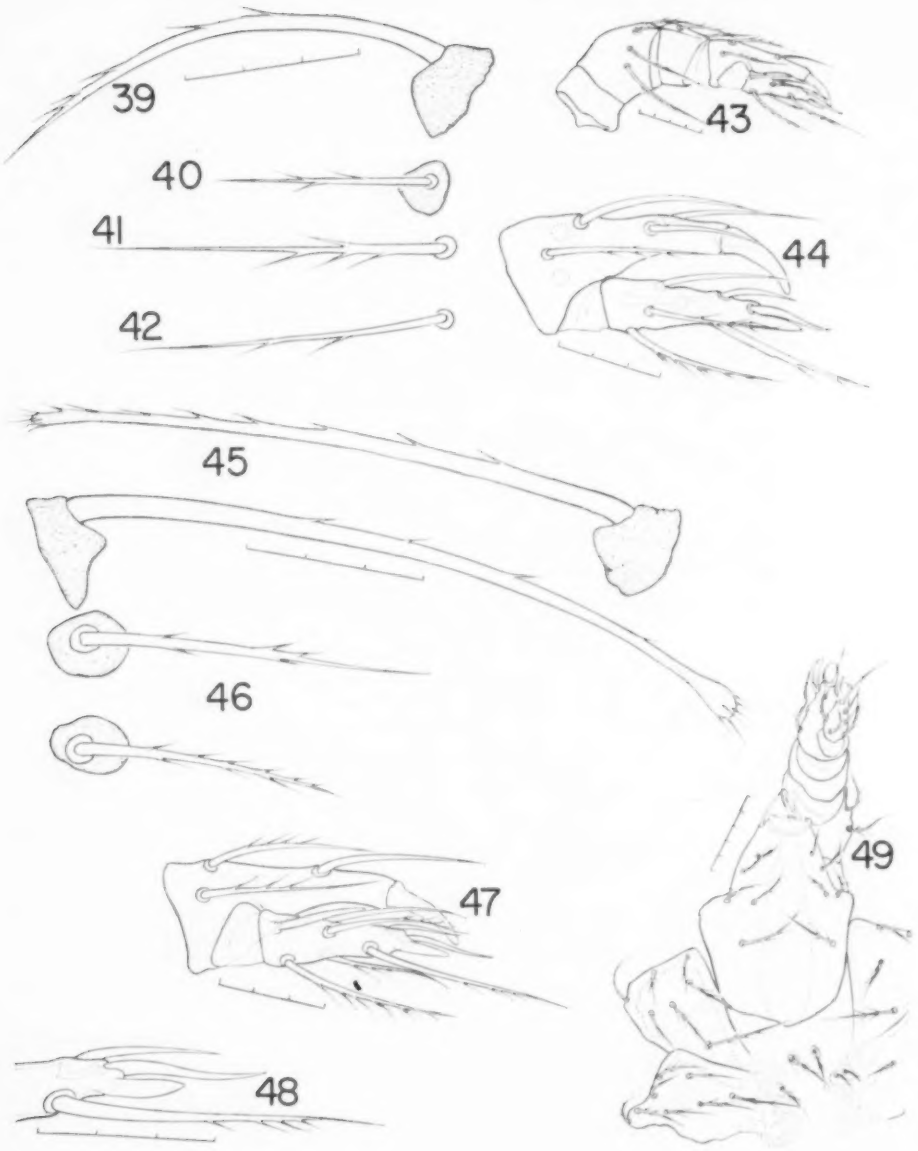
In a previous paper, the writer (1957: 407), presented a table of terms applied to the specialized setae of the legs of the Parasitengona in which "microfemorala, microgenuala, microtibiala (in part)" were listed as equivalent to solenidion$_3$ or s_3. The prefix *micro* should be deleted from each of these names. Likewise, solenidion$_4$ or s_4 has as its equivalent the term *tibiala* (in part)—not microtibiala as erroneously indicated in the table.

The term *prosensillar setae* was introduced by the writer (1958: 360–367) but was not defined. It had been shown in an earlier study (Newell, 1957: 398–400) that the most anterior setae of the scutum of Johnstonianidae could be (a) present and typically sensillar in form, closely resembling the posterior sensilla, (b) present, but more nearly resembling the other setae of the scutum than they do the sensilla, and (c) absent. In those Johnstonianidae, Trombiculidae, and Trombidiidae in which the homologues of the anterior sensilla are present but not sensilli*form*, these setae may be designated by the term *prosensilla.* These are typically the two anteromedian setae of the scutum. In many Trombiculidae, they are represented by an unpaired anteromedian *prosensillum.*

In the same paper (p. 384) the terms *odontus* and *paradont* were introduced. The name odontus is applied to the heavy terminal clawlike seta found on the tibia of the pedipalp. The term is utilized in preference to "claw," to avoid the implication of relationship to the tarsal claws. There is no relationship between the two types of "claw" in position, structure, or function, and different terms are desirable for the two kinds of structure. In many species a second and subterminal seta is found, usually quite near the insertion of the odontus, and this has been called the *paradont.*

DISTRIBUTION OF CHARACTER VARIANTS, ADULTS

	1	2	3	4	5
C. hurdi n. sp.	b	a	a	a	♀ 711 μ
C. delitescens n. sp.	a	b	b	a	♀ 513–711 (628)
C. grandjeani (André)	a	b	a	a	♀ 504
C. aelleni (Cooreman)	a	a	?	b	900



FIGS. 39–49. *Charadracarus delitescens*, n. sp., adult, female: 39, 40, two ventral hysterosomal setae; 41, seta of coxa IV; 42, seta of coxa II; 43, palp, posterior; 44, tibia and tarsus of palp, anterior; 45, major dorsal and marginal hysterosomal setae; 46, ventral hysterosomal setae; 47, tibia and tarsus of palp, posterior; 48, tip of tarsus of palp, posterior; 49, prosoma, ventral.

Charadracarus hurdi new species

FEMALE: Idiosoma of holotype 711 μ long, 459 μ wide, length/width 1.54. Scutum of essentially same form as found in *C. delitescens*, but sensilla not fusiform. Swollen distal portion with a number of small refractile points, and only a vestige of the shaft at the tip. Prosensillar setae considerably longer than the others. Setae appearing barbed at high magnifications, but relatively smooth at magnifications of 150× or lower. Posterior margin of plate rather deeply notched, and immediately anterior to the notch is a weakly defined, short, narrow crista. Cuticle faintly pigmented, yellow-brown in color. Ocular plates totally absent. Dorsal propodosomal setae of two series, major and minor, the major setae larger than the minor, but otherwise not differing in form (Figs. 29, 30). The tips taper uniformly to a very fine point, and are not expanded or tufted as in *C. delitescens* (Fig. 45). Setigerous sclerites very minute and difficult to observe. Coxa I with eight barbed setae each, supracoxal setae absent; coxal ring slightly open dorsally. Coxa II with seven or eight setae. Pars medialis coxae and intercoxal area as in *Charadracarus delitescens*. Coxae III and IV with six to eight setae each, usually eight. No trace of either apodemes or *Lassenia*-organ in membranous cuticle between II and III.

Base of gnathosoma and rostrum essentially as in *C. delitescens*. Chelicerae not in favorable position for study, but with only three feebly developed teeth behind the tip. Dorsal membrane well developed, slightly longer than one-half the length of the tarsus. Palpi with five free segments, trochanter with no indication of a fenestra on anterior surface. Femur with one seta dorsally and three setae on posterior margin, patella with two dorsal setae, tibia with six setae plus the terminal odontus (Figs. 2, 7). Tarsus with a solenidion very near the base of the segment plus seven setae more distally located. Of these, the two distidorsal ones are the heaviest and shortest, and are also smooth. The distal one of these two setae is typically eupathidiform with a distinct central canal and a moderately thick wall. Its homologue in *C. delitescens* is solid in several specimens examined by the writer. In the present species, the more proximal of these two setae is solid, without a central canal. The tip of the palpal tarsus is drawn out into a fingerlike projection.

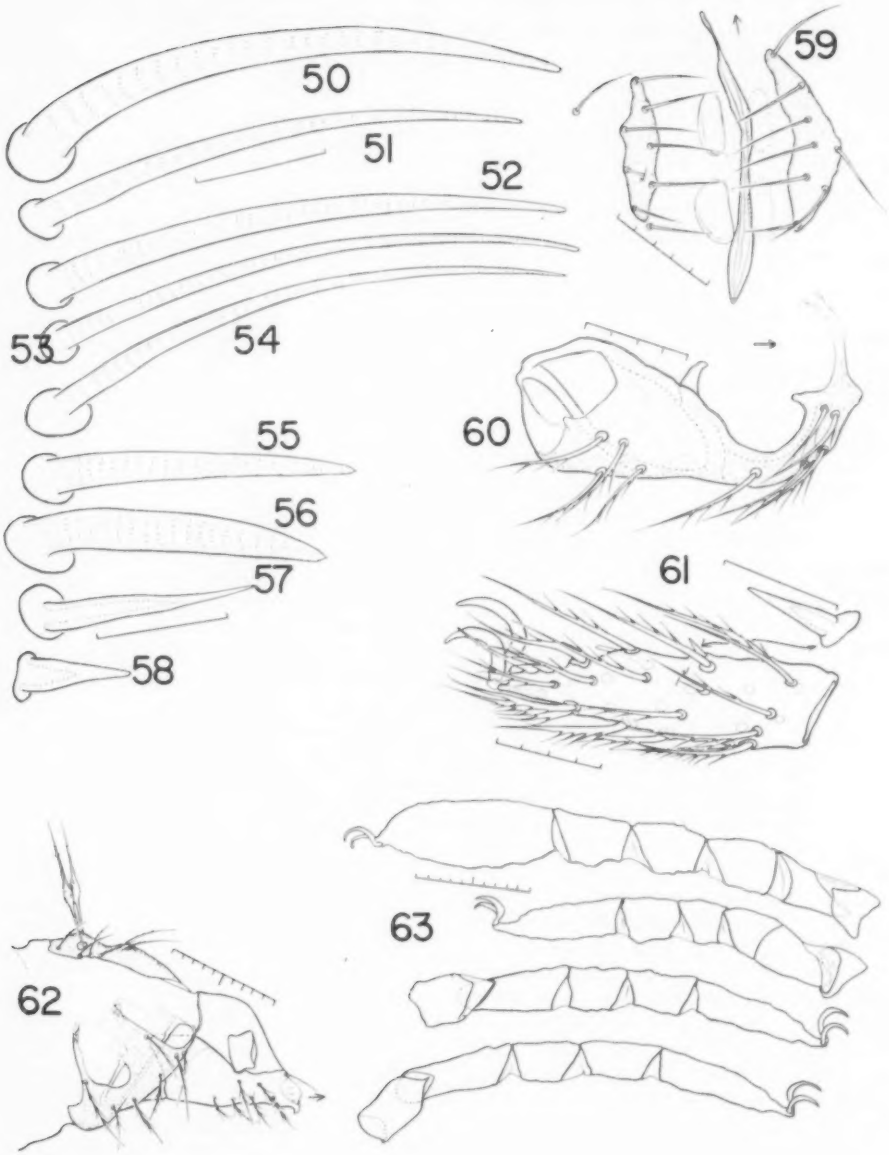
Femora I and II divided, III and IV undivided. Eupathidia confined to tarsi; vestigial setae absent. Tarsus I with a single s_1 at 0.72–0.74; usually with one or two s_2 between 0.56 and 0.65, one on anterior and one on posterior aspect of tarsus. Famulus$_1$ at 0.82. Approximately 16 or more eupathidia between 0.53–0.57*v* and 0.72–0.77*d*. Tarsus II with a single s_2 at 0.54–0.55, f_2 at 0.46–0.47, and a single eupathid at 0.88*p*. Tarsi III and IV each with a single s_3 at 0.12–0.32, the basal position probably more common. Remaining chaetotaxy essentially as in *C. delitescens*. Special features common to the two species are the slightly acuminate tips of s_2 and the apparently consistent difference in size of the dorsal solenidia of tibia IV (Figs. 27, 37).

TYPE LOCALITY: Point Barrow, Alaska, collected by Paul Hurd, Jr.

REMARKS: This species is very similar to *C. delitescens* new species, and to *C. grandjeani* (André). The most significant differences are in the form of the sensilla, and the difference in structure of major setae of the dorsal and marginal surfaces of the hysterosoma. The difference in form of the distal member of the group of two dorsal eupathidia at the end of the palpal tarsus differentiates *C. hurdi* from *C. delitescens*. This difference is especially significant since it shows that the scimitar-like setae found in this position in certain Johnstonianidae are modified eupathidia. Examples of this are found in the larva of *Centrotrombidium distans* (Newell 1957: 418, figs. 28, 29, 30), *Johnstoniana latiscuta* (Newell 1957: 431, fig. 92), and others.

Charadracarus delitescens new species

FEMALE: Body (Fig. 31) 513 to 711 μ long to tip of scutal spine, 270 to 351 μ wide, length/width 1.87 to 2.02; average 628 μ by 324 μ, length/width 1.94 (4 specimens). Sensilla of scutum (Fig. 36) with a fusiform swelling near the middle, this swelling bearing a few minute spines. Basal half of sensillum appearing faintly roughened, and under oil immersion a number of delicate barbs are visible (Fig. 83). Directly anterior to the sensilla are the prosensilla, slightly longer than the other setae. In addition,



FIGS. 50–63. *Charadracarus delitescens*, n. sp., adult, female: 50, s_1, tarsus I; 51, s_4, tarsus I; 52, s_4, tibia I; 53, s_3, tibia I; 54, s_3, telofemur I; 55, s_2, tarsus I; 56, s_2, tarsus II; 57, f_1; 58, f_2; 59, genital area, female; 60, coxae III and IV, lateral; 61, tarsus II, posterior; 62, prosoma, lateral; 63, outline drawings of legs I–IV.

there are four or five setae on either side, all of which are very faintly barbed. Anterior to the prosensilla, the scutum narrows to a sharp point which is so closely appressed to the dorsal surface of the propodosoma that it appears to be fused with it. However, the situation is probably the same in the adult as it is in the larva, in which the nasus is actually separate from the dorsal wall of the propodosoma. Between the areolae and extending to the small notch at the posterior margin of the scutum is a weakly defined crista metopica (Fig. 36). The lateral margins of the scutum are indistinct, fading almost imperceptibly into the very faintly striate membranous cuticle around it. Most of surface of scutum delicately punctate, region behind areolae with a number of faint panels. Dorsum of propodosoma with no setae lateral to scutum. Ocular plates completely absent. Dorsal and marginal hysterosomal setae sparse, of two grades, arising from small and only slightly elevated setigerous sclerites, the alveolus lying in the anterior half of the sclerite. Major setae with a strong tendency for the tip to be slightly enlarged and hollow, with a tuft of fine barbs; shaft sparsely barbed along one side. The minor setae arise from smaller setigerous sclerites, and their tips show no tendency toward enlargement. Membranous cuticle with striae visible only under the most favorable conditions. Coxae I with only six to eight setae; supracoxal setae absent. Coxae II with six setae each. Coxae III and IV with about ten and five setae each, respectively; coxal setae with four to eight long barbs. Coxal ring I scarcely closed dorsally, II completely open; III open, IV closed. Pars medialis coxae very faint, containing one or two setae on each side (Fig. 49); intercoxal area with only one or two setae. Other ventral setae with one to six fairly well-developed barbs. A broad transverse band of membranous cuticle behind coxae II devoid of setae. No trace of *Lassenia*-organ. Genital sclerites greatly reduced and difficult to see, containing only about eight smooth or sparsely barbed setae; paragenital sclerites totally absent. Between the genital sclerites lie the two pairs of acetabula. Genital opening considerably longer than the genital sclerite. Anus a very simple slit with no associated sclerites or setae, lying about half-way between the genital opening and the end of the hysterosoma.

Base of gnathosoma (Fig. 49) with six setae on each side (two specimens). Velum simple, directed anteriorly, a small circlet of fimbriae near the center.

Palpi (Fig. 43) five-segmented, trochanter a short ring, lacking a fenestra on the anterior surface. Femur with four setae, patella with two setae dorsally, tibia with six normal setae plus the heavy terminal odontus. Tarsus with the solenidion near the basal end, a series of three smooth dorsal setae (Figs. 44, 47), plus four other pectinate normal setae; terminal eupathid not hollow. Tip of tarsus drawn out into a narrow bladelike point as in the larva of this and other genera of the Johnstonianidae.

Femora I and II divided, III and IV undivided. Eupathidia confined to tarsi; vestigial setae absent. Tarsus I (four examined) with a single s_1 at 0.63–0.69*d* and typically with two s_2 between 0.62 and 0.67. Famulus$_1$ at 0.74–0.76. About 20 eupathidia present, lying between 0.57–0.60*v* and 0.63–0.79*d*. Tarsus II (five examined) with a single s_2 at 0.50–0.56*d*, f_2 at 0.37–0.52*d*, and a single eupathid at 0.85–0.88*p*. Tarsi III and IV each with a single s_3 at 0.13–0.19. Other specialized setae as shown in table. All tarsi with two simple claws, the posterior one slightly larger and more erect than the anterior one.

Chaetotaxy of legs approximately as shown in table (s = solenidia, e = eupathidia, f = famulus, v = vestigial setae, n = normal setae).

	tr	bf*		tf*	pa		ti		ta					
	n	n	s_3	n	s_3	v	s_2	s_4	s_1	s_2	s_3	s_4	e	f
I	1	4, 5	1	9, 10	5, 6	0	2, 3	3	1	2, 1	0	7	20	1
II	1	3	0	7	2	0	1	1	0	1	0	1, 2	1	1
III	2			10	2	0	2	0	0	0	1	0	0	0
IV	3			8	2	0	2	0	0	0	1	0	0	0

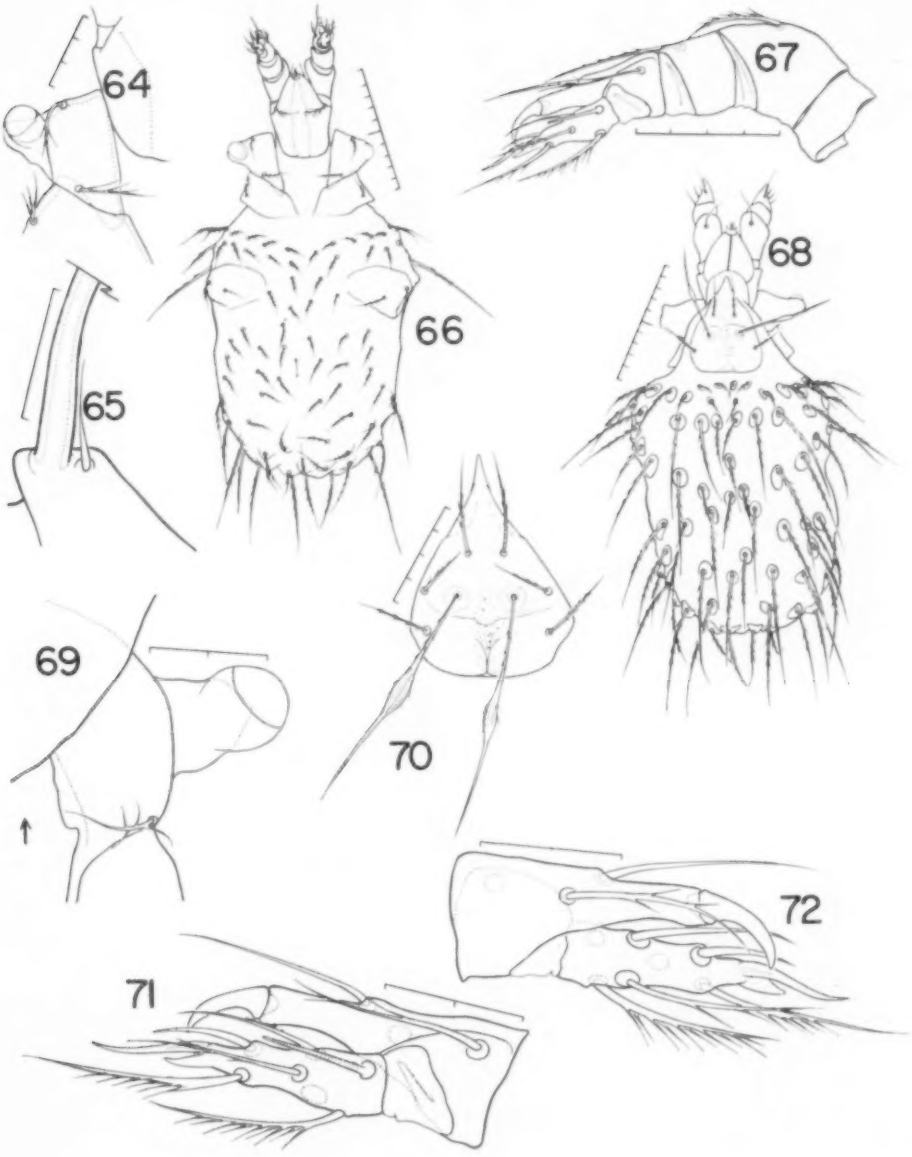
* Fused in legs III, IV only.

MALE: Very similar to female in most respects except for form of genitalia. Genital sclerites crescentic in form, faintly punctate, bearing nine slender smooth setae each; paragenital sclerites completely absent. A small internal corona bears only three pairs of setae which are readily visible, although others may be present. Only two pairs of acetabula present. Anus very small, lacking setae or sclerites.

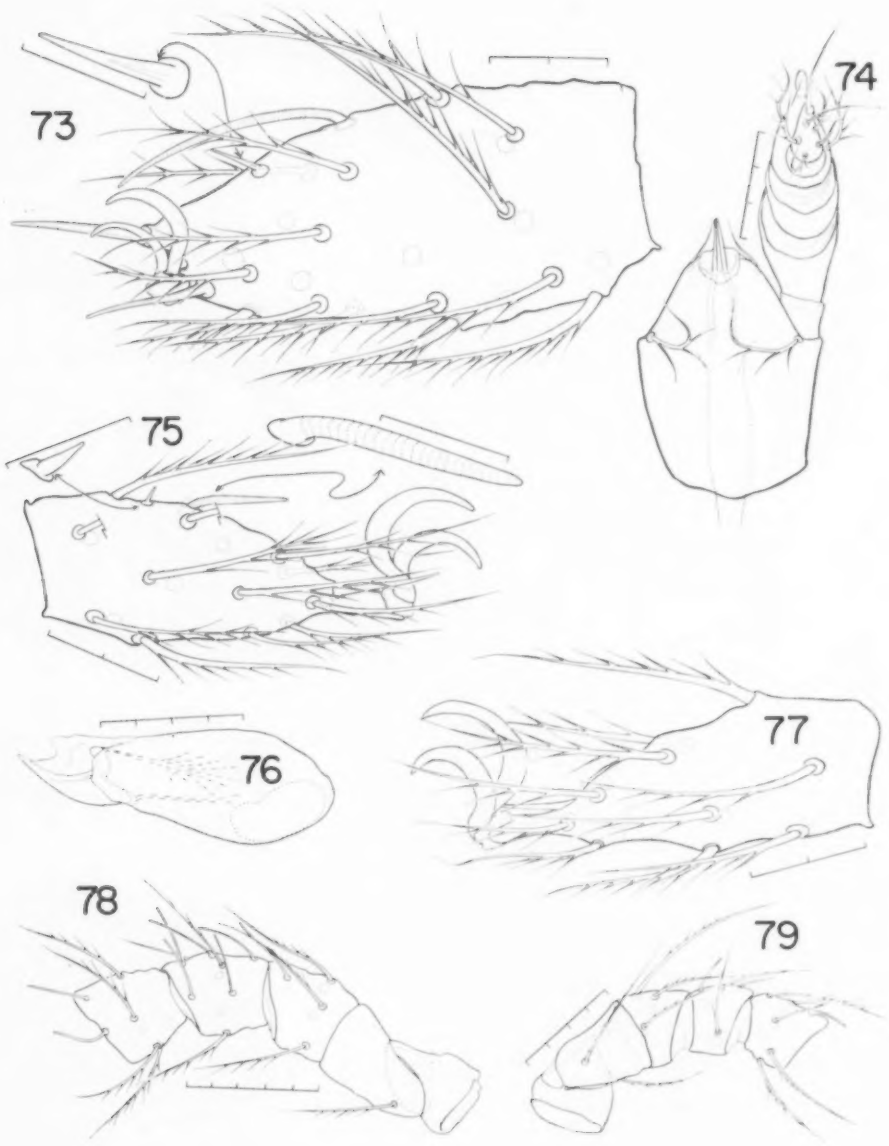
LARVA: Idiosoma 253–324 μ long to tip of scutal spine, 152–202 μ wide, length/width 1.53–1.76; average 295 μ long, 179 μ wide, length/width 1.65 (seven specimens). Scutum (Fig. 70) with four pairs of setae, the sensilla elongate, fusiform, bearing a number of barbs on both stalk and spindle. The spindle is collapsed in specimens mounted in Hyrax and sometimes even glycerine, but it is fully expanded in specimens in alcohol and Hoyer's medium. The other three pairs of setae on the scutum are similar in form, although the anterior setae (prosensilla) are somewhat longer than the others. Just anterior to the prosensilla, the scutum is drawn out into a very sharp tip, which in the living mite and in all preserved specimens seen by the writer is so closely applied to the dorsum of the propodosoma that it *appears* to be rigidly fused with the latter. This is in marked contrast with the situation in most other Johnstonianidae in which the nasus lies more or less free of the dorsal wall of the propodosoma. However, in dissected material, and in material mounted in Hoyer's medium, the nasus is seen to be a freely projecting spine. Behind the areolae is a transverse ridge or sharp declivity, and behind this a rudimentary crista metopica. A few irregular panels and minute punctae are present. Ocular plates absent. Dorsal and marginal setae arising from individual sclerites, the alveoli lying in the anterior half of the sclerite. Shaft with a number of minute barbs. The dorsal setae at the anterior margin of the hysterosoma are appreciably smaller than the others. Dorsal and marginal setae numbering 63 and 68 in the 2 specimens counted. Membranous cuticle mostly devoid of striae, although a few can be seen occasionally.

Coxal setae numbering 2–1–2, all slender, tapering, and bearing a number of fine barbs. The configuration of coxae I and II is markedly different from other genera of the Johnstonianidae, notably in the strongly transverse distal margins of I, the projecting lateral angles of I, and the exceptionally long medial margin of II. Supracoxal seta absent from I, coxal rings I and II both open dorsally, III with coxal ring very feebly developed dorsally. The urstigma is strongly protruded, the terminal portion hemispherical, attached to a stalk (Fig. 69). Membranous cuticle between coxae II and III with 21 ventral and marginal setae in each of the two specimens checked; 6 setae between coxae III of right and left sides. The same two specimens had 30 and 35 ventral setae behind coxae III and a total of 93 and 103 postscutal and postcoxal setae. The setigerous sclerites (omitted from Fig. 66) from which the ventral setae arise are smaller and much less distinct than those on the dorsal surface, as are the setae themselves. Anal anlage a simple line. No *Lassenia*-organ could be found in any of the specimens studied.

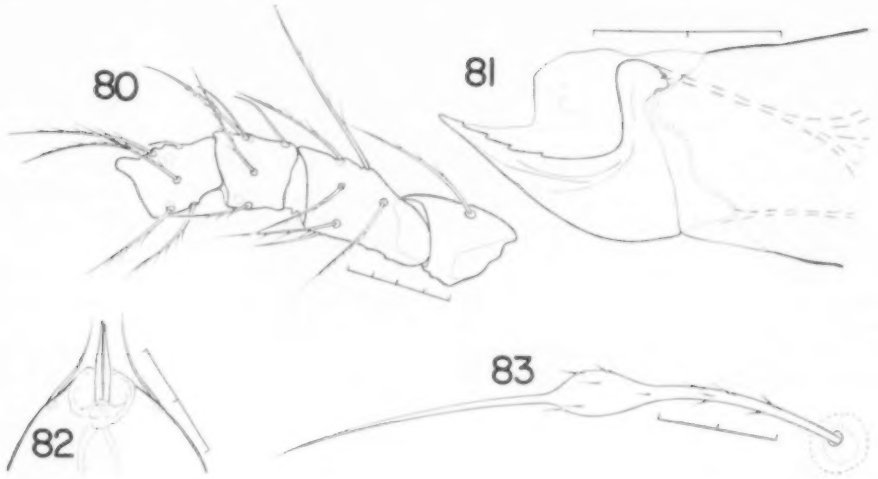
Base of gnathosoma without ventral setae (Fig. 74), supracoxal setae absent. A pair of setae laterally at base of rostrum, presumably the tritorostrals. Deutorostrals apparently absent, protorostrals slender, smooth. Velum simple, directed anteriorly. Chelicerae (Fig. 76) with ventral margin of distal membrane closely applied to the dorsal surface of the tarsal claw (in Hoyer's mounts, this membrane is distorted and lies free). Dorsal margin of tarsus with four sharp teeth visible under oil immersion. Palpi distinctly five-segmented, normally oriented. Trochanter a short cylinder without fenestra on anterior surface. Femur and patella with a single dorsal bihemipectinate seta; tibia with 3 slender setae plus the unidentate terminal odontus, which ends in a single point. Anterodorsal and posterodorsal setae of tibia with one to three delicate barbs, dorsal seta of tibia smooth. Tarsus of palp with solenidion at 0.09*p* and three setae at 0.30, 0.60 and 0.82*d*, these becoming progressively heavier toward the distal end. Beyond 0.82, the tarsus is continued as a thin sharp blade. In addition there are four other pectinate normal setae as shown in the figure. Morphologically, the palp of *Charadracarus* is virtually identical with that of both *Centrotrombidium* and *Diplothrombium;* however the most distidorsal seta is not flattened as in those genera,



FIGS. 64–72. *Charadracarus delitescens*, n. sp., larva: 64, coxa I and urstigma; 65, base of e_4 of tarsus I; 66, venter; 67, palp, posterior; 68, dorsum; 69, urstigma, left side, ventral medial view; 70, scutum; 71, tibia and tarsus of palp, posterior; 72, tibia and tarsus of palp, anterior.



FIGS. 73–79. *Charadracarus delitescens*, n. sp., larva: 73, tarsus I, posterior; 74, gnathosoma, ventral; 75, tarsus II, posteroventral; 76, chelicera; 77, tarsus III, posterior; 78, trochanter-tibia I, posterior; 79, trochanter-tibia II, posterior.



FIGS. 80–83. *Charadracarus delitescens*, n. sp., larva: 80, trochanter-tibia III, posterior; 81, tarsus and membrane of chelicera; 82, tip of rostrum, ventral; 83, sensillum.

but is cylindrical at the base, tapering gradually to a fine point. Podocephalic canals absent.

Legs I and II with basifemur and telofemur distinctly separated from each other, III with femur undivided, so that legs I and II have six free segments beyond the coxa while III has only five. Vestigial setae absent from patella and tibia of all legs; eupathidial formula 2–1–0. Tarsus I with solenidion at 0.51–0.59, f_1 at 0.67–0.77, e_1 and companion seta at 0.95–0.98; averages 0.55, 0.72, and 0.97 respectively (ten tarsi I). Tarsus II with f_2 at 0.32–0.39, s_2 at 0.40–0.47; averages 0.36 and 0.43 respectively (nine tarsi II). Other chaetotactic features of legs as shown in table. All tarsi with two claws, the posterior more erect than the anterior.

TYPE LOCALITY: Angeles National Forest, Los Angeles County, 2.1 miles (by road) northwest of Big Pines Ranger Station. Under black oak litter on north slope. June 10, 1957, collected by the writer.

Charadracarus grandjeani (André) 1930, new combination

Typhlothrombium grandjeani, André, 1930: 527–531.

T. grandjeani, Thor and Willmann, 1947: 219–220.

T. grandjeani, Cooreman, 1954: 14–17.

This is a humus inhabitant, collected in the park at Versailles, France, under *"rouseux."* André described their color as ". . . rouge pale, blanchissant rapidement dans l'alcool." *C. delitescens* is not colored in the living state, except for the yellowish sclerotized areas.

André's description was based on the adult, not on nymphs. The presence of only two pairs of genital acetabula in the Johnstonianidae generally indicates a nymph, but *Charadracarus* is an exception. André described a well-developed spiniform seta anterodistally, in addition to the odontus and four long setae, making a total of six for the segment. The writer has studied the type slide, and the "spiniform seta" actually is only a little shorter than the other setae of the tibia, other than the odontus, and has the same form as in *C. delitescens* and *C. hurdi* (Figs. 7 and 44 of this paper).

Charadracarus aelleni (Cooreman) 1954, new combination

Typhlothrombium aelleni, Cooreman, 1954: 14–17.

This is a cavernicolous species from the Jura Range, Switzerland, Grotte de l'Echelette, alti-

tude 1220 meters. It is the only one of the four species in which there is a well-developed paradont on the tibia of the palp. It resembles *C. delitescens* and *C. grandjeani* in the fusiform sensilla. It resembles *C. hurdi* in the filiform shape of the major setae. Whether or not the paradont is a new seta in this species or whether it is a modified normal seta is difficult to say. Cooreman showed three normal setae on the posterior surface of the palpal tibia and two on the anterior surface, in addition to the odontus and paradont, making a total of seven setae for the tibia. In the other three species, there are six setae in addition to the odontus, but none of these assumes the character of a paradont.

REFERENCES

ANDRÉ, M. 1930. Sur une nouvelle espèce française d'Acarien, appartenant au genre *Typhlothrombium* Berlese. Bull. Mus. Hist. Nat., Paris, ser. 2, 2(5): 527–531.

BERLESE, A., and G. LEONARDI. 1901. Acari sud americani. Zool. Anz. 25(659): 12–18.

——— 1910. Brevi diagnosi di generi e specie nuovi di Acari. Redia 6(2): 346–388.

COOREMAN, J. 1954. Notes sur quelques Acariens de la faune cavernicole. Bull. Inst. Sci. Nat. Belg. 30(34): 1–19.

NEWELL, I. M. 1957. Studies on the Johnstonianidae (Acari, Parasitengona). Pacif. Sci. 11 (4): 396–466.

——— 1958. Specific characters and character variants in adults and larvae of the genus *Paratrombium* Bruyant 1910 (Acari, Trombidiidae), with descriptions of two new species from western North America. Pacif. Sci. 12(4): 350–370.

Notes on the Hawaiian Frigate Mackerel of the Genus *Auxis*

WALTER M. MATSUMOTO[1]

A NEW DISTRIBUTION RECORD for a long-corseletted frigate mackerel of the genus *Auxis* was established on November 30, 1957, with the capture of 21 specimens in the central Pacific Ocean. These fish were taken from the same school together with five short-corseletted frigate mackerels. The catch was made from the research vessel "John R. Manning" of the Pacific Oceanic Fishery Investigations (POFI), by pole-and-line fishing, one mile offshore, two miles northwest of Cape Kaea, Lanai. Although the long- and short-corseletted *Auxis* are known from both sides of the Pacific, only the short-corseletted form has been reported heretofore from the central Pacific area.

As is the case with some of the other scombrids, the taxonomy of this genus is not very clear. Although the identity of the short-corseletted form has been well established as *A. thazard* (Lacépède 1802), the nomenclature of the long-corseletted form has been confused because of incomplete description and subsequent misnaming by other workers. It is hoped that this paper will help to clarify the nomenclature of this genus.

The long-corseletted form of the western Pacific has been identified by various names. Kishinouye (1915: 13–14) recognized two species of *Auxis* in Japanese waters, to which he ascribed the names *A. hira* and *A. maru*. The former species was described as having a short corselet which ended slightly posterior to the pectoral fin, whereas the latter was described as having a long corselet which extended to the anal fin. Under the description of the latter species, Kishinouye stated that "Bleeker's *tapeinosoma* may also be this species, but the figure and description of this species are very rough and unclear." In recent years Herre and Herald (1951: 319) and Wade (1949: 229) applied the name *tapeinosoma* to the Philippine long-corseletted form. A review of Bleeker's original description (1854: 408), however, discloses that *tapeinosoma* is definitely a short-corseletted form, for according to him the corselet ends "slightly posterior to the pectoral fins." This character agrees with the short corselet of *thazard* and *hira*, and therefore, *tapeinosoma*, as used by Herre and Herald, and by Wade, in identifying the long-corseletted species is a misnomer.

The appropriate name for the western Pacific long-corseletted species seems to be *A. thynnoides* Bleeker. Examination of Bleeker's (1855: 301) original description of the type specimen which was taken at Ternate, East Indies, and which is now in the Leiden Museum, clearly indicates that his specimen is the long-corseletted form, for he states that the corselet along the lateral line ends "far behind the pectoral fin." The writer's interpretation of Bleeker's description is confirmed by John E. Fitch (through private correspondence), who has checked the type specimen. It is apparent from the original description and from Fitch's information that *thynnoides* is the earliest available name for the western Pacific long-corseletted species. The Hawaiian form described here is identical with that from the Philippine waters and agrees well with the type specimen described by Bleeker. Consequently, it is given the name *A. thynnoides* Bleeker.

A. thazard has been described many times by previous workers. Nevertheless, in order to facilitate the comparison between this species and *thynnoides*, the descriptions of both are presented.

DESCRIPTIONS OF SPECIES

Auxis thynnoides Bleeker

Fig. 1

This description is based on 20 specimens which are now deposited at the POFI laboratory, Honolulu, Hawaii.

[1]Fishery Research Biologist, Bureau of Commercial Fisheries, Hawaii Area, Honolulu. Manuscript received September 17, 1958.

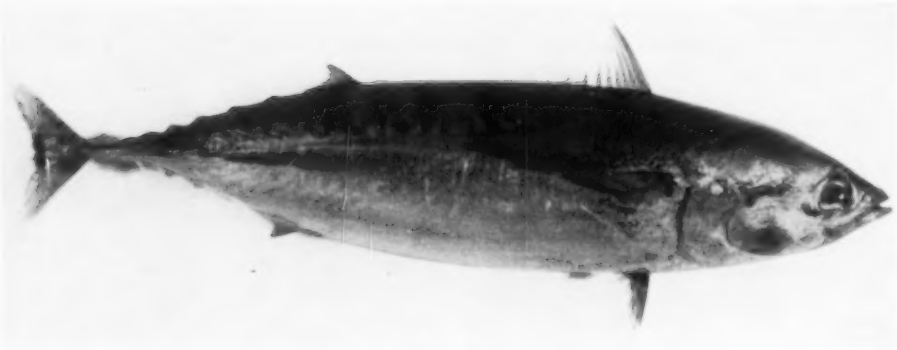


FIG. 1. *Auxis thynnoides* Bleeker.

Dorsal X–XI, 10–11, 8. Anal 12–13, 7. Gill rakers 10–11 + 1 + 32–36 = 43–48. Total length 262–290 mm.

Body robust, fusiform, almost cylindrical in cross section. Snout short, pointed. Mouth moderate; gape to slightly past anterior margin of pupil. Each jaw with single row of small, weak teeth. Palatines and vomer toothless. Dorsal fins well separated. Dorsal interspace slightly greater than half the distance between origins of first and second dorsals.

Vertebrae 20 + 19 = 39, including urostyle. First haemal arch on 8th vertebra; first closed haemal arch and first haemal spine on 21st vertebra. Haemal canal borne away from body of vertebra by pedicles [of Starks (1910: 97) = epihaemal processes of Kishinouye (1923: 460)].

Body naked, except for corselet of scales. Corselet along lateral line extends beyond vertical through posterior end of second dorsal. Corselet 16–18 scale-rows wide below origin of second dorsal fin. Lateral line more or less undulating, without any pronounced arch.

Body markings consist of 14–16 dark, nearly vertical bars over bluish background above lateral line. Bars often broken into spots. Dark continuous band over top of head and along dorsal margin of body. The band more or less uniform in width to end of second dorsal, whence it narrows posteriorly to base of caudal fin. Body below lateral line silvery white and free of markings or spots.

Auxis thazard (Lacépède)
Fig. 2

This description is based on five specimens which are deposited at the POFI laboratory, Honolulu, Hawaii.

Dorsal XI, 10–12, 8. Anal 13, 7. Gill rakers 9–10 + 1 + 28–31 = 39–42. Total length 272–283 mm.

Body robust, more or less compressed laterally. Snout short, pointed. Mouth moderate; gape to well past anterior edge of pupil. Each jaw with single row of small, weak teeth. Palatines and vomer toothless. Dorsal fins well separated. Dorsal interspace less than half the distance between the origins of the first and second dorsals.

Vertebrae 20 + 19 = 39, including urostyle. First haemal arch on 8th vertebra; first closed haemal arch and first haemal spine on 21st vertebra. Haemal canal borne away from body of vertebra by pedicles.

Body naked, except for corselet of scales. Corselet along lateral line extends posteriorly to about two-thirds the distance from the origin of first dorsal to the origin of second dorsal. Lateral line only one or two scale-rows wide beneath second dorsal origin. Lateral line more or less undulating, without any pronounced arch.

Body markings about 16 dark, oblique bars running posterodorsally and overlying bluish background above lateral line. Bars variable in number and often broken into spots. Dark continuous band over top of head and along dorsal

margin of body. The band more or less uniform in width to above tip of pectorals whence it narrows posteriorly to base of second dorsal finlet. Body below lateral line silvery white and free of markings or spots.

DISCUSSION

Several distinguishing characters are noted in the two types of *Auxis* described here. The most obvious of these is the corselet formation along the lateral line. In *thazard* the corselet narrows abruptly toward the lateral line and ends at about two-thirds of the distance from the origin of the first dorsal to the origin of the second dorsal fin. On larger specimens, 350 to 400 mm. long, according to Wade (1949: 234), the corselet tapers less rapidly than in smaller specimens, but in no case does it extend to the level of the second dorsal origin. In contrast to this the corselet of *thynnoides* tapers very gradually and terminates between the first and second dorsal finlet. In the Hawaiian specimens the corselet is still 16 to 18 scale-rows wide beneath the origin of the second dorsal fin. In the smaller Philippine specimens, whose total lengths range between 195 and 235 mm., the corselet beneath the second dorsal fin is from 9 to 15 scale-rows wide.

Upon examining the corselet of these specimens, it was noticed that the largest scales were adjacent to the lateral line, and that the size of the scales diminished on each succeeding scale-row away from the lateral line. From this observation and also from the previous one, that the larger Hawaiian specimens have more scale-rows than the smaller Philippine specimens, it was suspected that the width of the corselet increased with growth of the fish. An analysis of the regression of number of scale-rows on fish length (Hawaiian and Philippine material combined) yielded the equation, $Y = 0.078 \times -4.55$, which is shown graphically in Figure 3. The highly significant regression coefficient ($b = 0.078$; $t = 12.14$, $P < 0.001$, at 19 degrees of freedom) indicates that the number of scale-rows increases as the body length does, and that therefore, the variation in corselet width between the Philippine and Hawaiian specimens represents growth rather than a species difference.

An interesting character, one which has seldom been used previously in separating the two forms of *Auxis*, is the configuration of body markings. In both species the dorsal half of the body contains a number of dark bars. Although these bars vary in number and are sometimes broken into spots, their position on the body is distinctive. In *thazard* the bars lie obliquely in a posterodorsal direction. In addition to these bars, the dorsal surface of the body is marked with a dark longitudinal band which is as wide as the interorbital space and which extends evenly from the snout to above the tip of the pectoral fin. It then tapers gradually to about the base of the second dorsal finlet. In *thynnoides*, on the other hand, the bars lie in a more

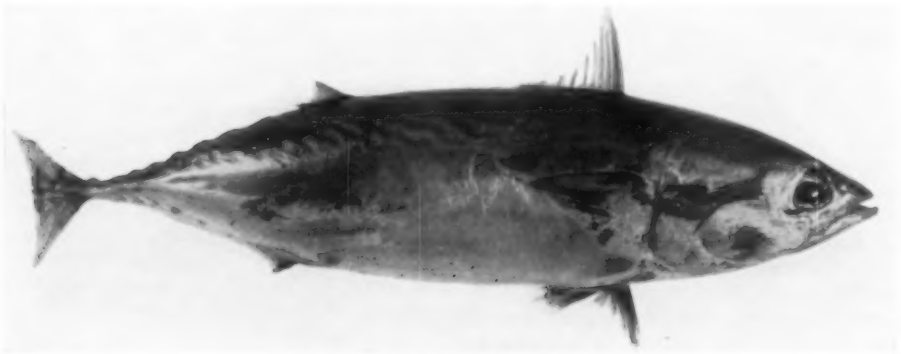


FIG. 2. *Auxis thazard* (Lacépède).

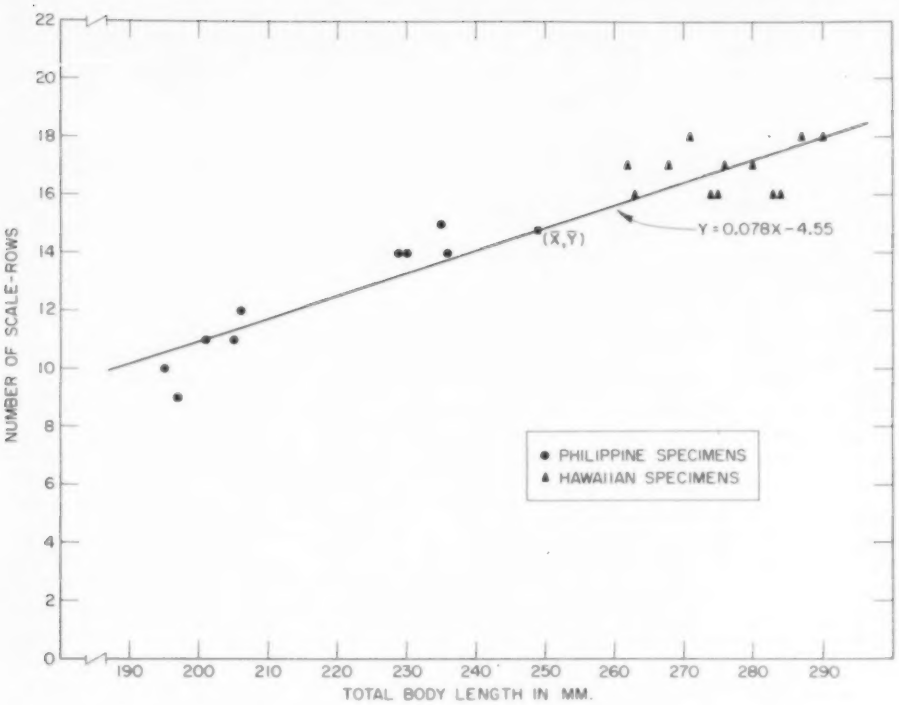


FIG. 3. Regression of the number of scale-rows on total body length of *Auxis thynnoides*.

or less vertical direction, and the dark longitudinal band on the dorsal surface of the body does not taper noticeably until it reaches the end of the second dorsal fin, whence it continues to the base of the caudal fin, tapering very gradually.

Another character often mentioned by investigators in separating the two forms of *Auxis* is the difference in the roundness of the body. In both species the ratios of body length (fork length) to body width are nearly identical (6.04 to 6.56 in *thazard;* 6.02 to 6.58 in *thynnoides);* however, the ratio of body length to body depth of *thynnoides* (4.55 to 4.98) is greater than that of *thazard* (4.32 to 4.56). Consequently, *thynnoides* appears fusiform, whereas *thazard*, because of its greater depth, appears laterally compressed. In visual comparison, this difference is so slight that it requires an unusually keen observer or one who has had practice in this observation to notice the difference.

Nearly all of the characters examined on the two species exhibit very small differences which are difficult to recognize in the field. Even the relatively more obvious corselet difference would elude detection unless the observer was looking for it specifically. This being the case, the question arises as to whether *thynnoides* was present in these waters previous to this capture but was undetected, or whether its recent capture indicates a movement of this fish into the area.

REFERENCES

BLEEKER, PIETER. 1854. Faunae ichthyologicae japonicae species novae. Natuurk. Tijdschr. Ned.-Ind. 6: 395–426.

——— 1855. Vijfde bijdrage tot de kennis der

ichthyologische fauna van Ternate. Natuurk. Tijdschr. Ned.-Ind. 8:295-304.

HERRE, A. W., and E. S. HERALD. 1951. Noteworthy additions to the Philippine fish fauna with descriptions of a new genus and species. Philipp. J. Sci. 79(3): 309–340.

KISHINOUYE, KAMAKICHI. 1915. A study of the mackerels, cybiids, and tunas. Sui. Gak. Ho (Proc. Sci. Fish. Ass. Tokyo) 1(1): 1–24. [Spec. Sci. Rep. U. S. Fish Wildl. Serv. (Fish.) 24: 1–14. 1950. Translated from the Japanese by W. G. Van Campen.]

——— 1923. Contributions to the comparative study of the so-called scombroid fishes. J. Coll. Agric. Tokyo 8(3): 293–475.

STARKS, EDWIN C. 1910. The osteology and mutual relationships of the fishes belonging to the family Scombridae. J. Morph. 21(1): 77–99.

WADE, CHARLES B. 1949. Notes on the Philippine frigate mackerels, family Thunnidae, genus *Auxis*. Fish. Bull. U. S. 51(46): 229–240.

Taxonomic Notes on the Ants *Ponera leae* Forel and *Ponera norfolkensis* (Wheeler) (Hymenoptera–Formicidae)

R. W. TAYLOR[1]

THE RECENT RECOGNITION by Wilson (1957) of several Pacific species groups within the ant genus *Ponera* has done much to clarify the relationships, both taxonomic and biogeographical, of various scarce species occurring in this area. The present note has been prepared in order to record the addition of two further species to Wilson's *Ponera tenuis* group: these are *P. leae* Forel of Tasmania, and *P. norfolkensis* (Wheeler) of Norfolk Island. The recognition of the true position of these species has resulted from studies directed towards the identification of specimens of *P. leae* collected several years ago at Paihia, New Zealand, by Dr. K. P. Lamb of the Plant Diseases Division, Auckland. Further notes on the biology of *P. leae* in New Zealand will be presented elsewhere; at present it is sufficient to point out that this ant has almost certainly been introduced into that country from Tasmania, or from some other part of Australia.

Since this work is largely additional to that of Wilson (*loc. cit.*) I have used his descriptions as a basis in preparing the measurements, indices, and terminology used below.

Ponera leae Forel

Ponera leae Forel, 1913, Bull. Soc. Vaud. Sci. Nat. 49: 173–196; p. 175, worker, original description.

TYPE LOCALITY: Tasmania.

The following measurements and notes are based upon the holotype worker in the Museum d'Histoire Naturelle, Geneva; and on two workers from Paihia, New Zealand, in the collection of the Plant Diseases Division, Auckland.

HOLOTYPE WORKER: HW 0.40 mm., HL 0.55 mm., SL 0.35 mm., CI 73, SI 87.5, PW 0.30 mm., PH 0.29 mm., petiolar node length 0.21 mm., dorsal petiole width 0.25 mm.

HOMOEOTYPE WORKERS: HW 0.40 mm., HL 0.55 mm., SL 0.34 mm., CI 73, SI 85, PW 0.30 mm., PH 0.29 mm., petiolar node length 0.21 mm., dorsal petiole width 0.25 mm.

Length 2.5 mm. Mandibles with three well-developed teeth occupying approximately the apical third of the masticatory border, and with an indeterminate number of minute denticles behind. Eyes minute, consisting of a single facet with a maximum diameter of about 0.01 mm. Antennal club massive, distinctly four jointed, considerably longer than the remainder of the funiculus. Petiolar node (Fig. 1) in side view massive, subrectangular, tapering slightly dorsally; seen from above its dorsal surface forming an almost complete half-circle, the posterior face flat to very feebly concave. Subpetiolar process somewhat reduced, with a large and distinct anterior fenestra. Other characters as described by Forel (1913).

Forel (1913) considered that eyes were not developed in this species, and Wheeler (1927) noted that pigment spots were present in some specimens, while others showed no sign of eyes. It is clear that Forel overlooked the eyes which I have shown to be present in his type of *leae;* and in view of the minute size of these it is probable that Wheeler was also in error in his interpretation of the material he examined. However, Wheeler's observation must stand, with reservation, until further material becomes available, as the specimens examined by him have apparently been lost, and so cannot be checked.

RELATIONSHIPS: This species is clearly very closely related to *P. caledonica* Wilson, but differs in the following characters:

(1) The eye of *leae* is somewhat smaller; with a maximum diameter of only about 0.01 mm., as compared with 0.02 to 0.03 mm. in *caledonica.*

(2) The lateral faces of the propodeum are much more densely shagreened, with extremely

[1] Zoology Department, University of Auckland.
Manuscript received February 24, 1959.

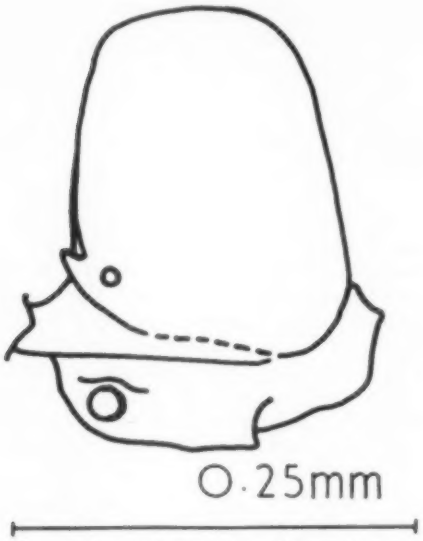


FIG. 1. *Ponera leae* Forel. Petiolar node in side view. Drawn from a specimen collected at Paihia, New Zealand.

fine longitudinal striae, than are those of *caledonica;* they appear as subopaque, whereas in *caledonica* they are moderately to strongly shining.

(3) The punctulation of the first and second gastric segments is somewhat more coarse, and close, than that of *caledonica.*

(4) The body colouration is darker than that of *caledonica,* medium reddish brown, as opposed to light reddish brown.

Ponera norfolkensis (Wheeler)

Ponera leae oculata Wheeler, 1927, Proc. Amer. Acad. Arts Sci. 62: 121–153; pp. 130–131, fig. 1, worker, queen, original description.
TYPE LOCALITY: Norfolk Island.

Ponera leae norfolkensis Wheeler, 1935, Occ. Pap. Bishop Mus. 11(11): 1–56; p. 13, new name for *oculata,* name preoccupied.

The following details have been supplied by Dr. Wilson; they are based upon two syntype workers in the Museum of Comparative Zoology, Harvard University.

(1) HW 0.43 mm.–0.44 mm., HL 0.56 mm.–0.57 mm., SL 0.36 mm., CI 76–77, SI 84–85, PW 0.35 mm., petiolar node length 0.20 mm., dorsal petiole width 0.29 mm. (PW, petiolar length, and petiolar width are based on one specimen only.)

(2) Size larger than that of either *leae* or *caledonica.*

(3) Eye developed as in *caledonica.*

(4) Propodeal sculpturing as in *leae.*

DISCUSSION: Within the *Ponera tenuis* species group Wilson (1957) recognized several subgroups. One of these, his *caledonica* subgroup, included *P. caledonica* of New Caledonia, and the east Australian *P. exedra* Wilson. The major features of this subgroup are the relatively large size, elongated head, thick petiolar node, and light colouration; characters which are shared also by *leae* and *norfolkensis,* discussed above. Accordingly the subgroup may be extended to include these two species, and by nomenclatural priority must now become known as the *Ponera leae* subgroup.

In addition, relationship between *leae, norfolkensis,* and *caledonica* is particularly marked. Indeed Wilson, who has checked one of my *leae* homoeotypes against the type series of *caledonica,* has noted (*in litt.*) that the characters of *leae* fall within the range of variation of *caledonica,* in such important characters as size, petiole shape, and head and scape proportions. Nevertheless the diagnostic features listed above seem to be characteristic. *P. norfolkensis* also seems to be a "good species," considering the characters listed above, and the differences between it and *leae* noted by Wheeler (1927).

Within the *P. leae* subgroup, therefore, *leae, norfolkensis,* and *caledonica* form a very closely related assemblage distinct from *P. exedra.* These three forms may best be considered as constituting a biological superspecies, with three apparently distinct allopatric species developed on New Caledonia, Norfolk Island, and Tasmania. Full specific recognition has been accorded these forms due to the apparently discontinuous nature of the variation in their diagnostic features, and the known facts regarding the often very subtle species differences in other, better represented, species of *Ponera.*

KEY TO THE *Ponera leae* SUPERSPECIES

In the key to the species of the *tenuis* group presented by Wilson (1957) all three of these species key out to *caledonica;* they may be differentiated as follows:

1. Slightly larger species, HW 0.42 mm. to 0.44 mm. (Norfolk Island) ..... **norfolkensis**
   Slightly smaller species, HW 0.38 mm. to 0.40 mm. 2
2. Eye diameter 0.02 mm. to 0.03 mm.; colour medium reddish brown; lateral faces of propodeum feebly to strongly shining (New Caledonia) ..... **caledonica**
   Eye diameter about 0.01 mm.; colour dark reddish brown; lateral faces of propodeum densely shagreened and subopaque (Tasmania and New Zealand) ..... **leae**

ACKNOWLEDGMENTS

Insofar as *P. leae* and *P. norfolkensis* are very poorly represented in collections, a number of Australian entomologists have given assistance in attempting to locate specimens for the author. I wish to extend my thanks to them, particularly to Father J. J. McAreavey of Melbourne, Mr. N. M. Hudson of Hobart, and Dr. E. T. Giles, late of the Museum of South Australia, Adelaide.

Special thanks are due to Dr. Ch. Ferriere of the Museum d'Histoire Naturelle, Geneva, for arranging the loan of the type of *P. leae* from the Forel collection; and to Dr. E. O. Wilson of Harvard University, for his most generous direction and for assistance in providing paratype specimens of *P. caledonica,* and notes on the type series of *P. norfolkensis.* I wish also to thank the Director and Dr. K. P. Lamb of the Plant Diseases Division, Auckland, for the loan of specimens of *P. leae.*

REFERENCES

FOREL, A. 1913. Fourmis de Tasmanie et d'Australie recoltees par MM. Lea, Froggatt, etc. Bull. Soc. Vaud. Sci. Nat. 49: 173–196.

WHEELER, W. M. 1927. The ants of Lord Howe Island and Norfolk Island. Proc. Amer. Acad. Arts Sci. 62: 121–153.

——— 1935. Checklist of the ants of Oceania. Occ. Pap. Bishop Mus. 11(11): 1–56.

WILSON, E. O. 1957. The *tenuis* and *selenophora* groups of the ant genus *Ponera* (Hymenoptera-Formicidae). Bull. Mus. Comp. Zool. Harv. 116(6): 355–386.

NOTES

Fatal Shark Attack, Oahu, Hawaii, December 13, 1958[1]

ALBERT L. TESTER[2]

ON DECEMBER 13, 1958, a large shark believed to be *Galeocerdo cuvieri*, the tiger shark, was responsible for the death of 15-year-old William (Billy) Weaver in water about 12 feet in depth off Lanikai on the windward (east) coast of the island of Oahu, Hawaii. Although the story of the tragedy was well covered in the local newspapers, a condensed version has been prepared which includes information of interest to scientists who are concerned with factors motivating shark attack. In preparing the account which follows, conflicting stories have been resolved and additional information has been obtained by correspondence and interview with several of the persons directly or indirectly involved. Additional information on shark identification, shark fishing, etc., was supplied by the staffs of the Board of Agriculture and Forestry, Division of Fish and Game, and the Bureau of Commercial Fisheries, Pacific Oceanic Fisheries Investigation.

DESCRIPTION OF THE INCIDENT

A party of six boys including the victim (Billy Weaver) and five friends (Terry Oakland, age 14; Tom Replogle, 14; Garrett Goo, 13; Brook Collins, 10; and Charles Collins, 9) were swimming and surfing about noon off a reef near Twin Islands (Mokulua Island) about ¼ mile off Lanikai (Fig. 1). They had three surfboards which were light green, red and "natural" in color, three air mattresses which were red on one side and blue on the other, and an 8-foot sailboat, without mast or sail, which was white in color and anchored near the reef. The sky was clear but the water was rough with whitecaps and good-sized waves. The boys kept together; never was one more than 75–100 feet from the others.

About 1 p.m. Brook Collins was resting in the boat with his surfboard across it; Charles Collins was resting on his surfboard beside the boat, holding on to the anchor line—he was afraid of the waves after "pearl diving" on one. The four older boys were surfing off the reef. Garrett Goo and Terry Oakland, on air mattresses, and Tom Replogle, on the light green surfboard, caught a wave and rode a short distance. Billy Weaver, on an air mattress, failed to catch the wave. When about 50 yards away, the boys noticed that Weaver was clinging to the mat, apparently in difficulty. On hearing a feeble cry for help, Goo swam over, saw blood in the water, and realized that Weaver had lost a leg. The three boys attempted to support the victim and called to Brook Collins to bring the boat over. After some difficulty in freeing the anchor from the coral, Brook Collins hauled it up and started rowing. As the boat was coming too slowly, Garrett Goo swam to it, climbed aboard, and pushed the surfboard off the boat to make more room for rowing. Brook Collins, standing up in the boat, saw a large shark surface 30 feet away, and screamed "Shark." The two boys supporting the victim pushed him toward the reef, and swam frantically to the boat. By the time they reached the boat he had disappeared. As they could not approach the spot where he had been last seen without risk of swamping the boat in the waves, the boys rowed to shore and summoned help.

A Fire Department rescue squad arrived at 2:30 p.m. and sped to the scene in a borrowed 25-foot Chris-Craft boat. Local residents in other boats joined in the search. The body was finally

[1] Contribution No. 125 of the Hawaii Marine Laboratory, University of Hawaii. Manuscript received April 6, 1959.

[2] Department of Zoology and Entomology, University of Hawaii.

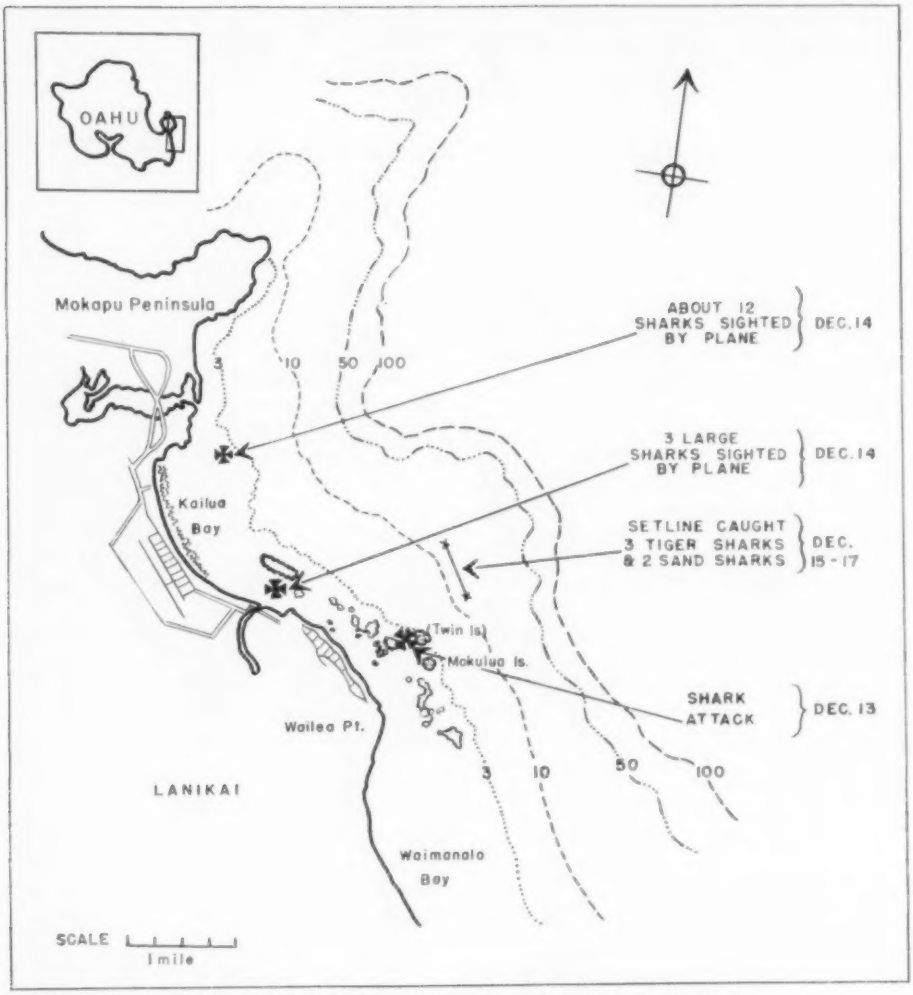


FIG. 1. Coastline of Oahu, showing places where sharks were sighted.

located by a helicopter crew from Kaneohe Marine Air Station in a hole in the reef seven feet deep, and it was recovered by a local resident, John G. Ferreira, by skin diving. The shark, variously estimated at 15 to 25 feet in length, was still cruising nearby, its dorsal fin about 1½ feet out of the water. Attempts to revive the boy with artificial respiration both on board the boat and on shore were unsuccessful. A deputy coroner stated the shark bite had stripped away the flesh six inches above the knee and completely removed the right leg from the knee joint. The victim died from loss of blood, drowning, shock, or a combination of all three.

ATTEMPTS TO CATCH THE SHARK

On December 14, 1958, attempts were made by employees of the Division of Fish and Game

and by local residents to capture the shark. The Fish and Game employees set an 8-hook shark setline in the shallow water off the reef where the incident had taken place but without success. In the meantime, Piper Cub pilots searching the area spotted two schools of sharks in the adjacent waters of Kailua Bay (Fig. 1). One group of three large sharks was reported cruising just off Flat Island, 200 yards offshore from the public beach. The second school of about a dozen sharks was spotted on the north end of the bay. Local residents converged on both areas hoping to kill the sharks with high-powered rifles but were unsuccessful.

From December 15 through December 17, 1958, under the personal direction of C. Eric Reppun, President, Board of Agriculture and Forestry, and Michio Takata, Director, Division of Fish and Game, the Division's research vessel "Makua" fished a 24-hook setline (flagline or buoyed longline) offshore from the reef in about 70–80 feet of water (Fig. 1). The catch consisted of three tiger sharks and two sand sharks. Two of the tiger sharks were 12 feet in length and weighed 750–800 pounds; the third was 11 feet in length and weighed 410 pounds. The two sand sharks *(Eulamia menisorrah?)* were eight to nine feet in length and weighed about 350 pounds.

IDENTITY OF THE SHARKS

It seems most likely that the fatal attack was by a large tiger shark (*Galeocerdo cuvieri*). One of the searchers described the shark (to Herbert Mann, Bureau of Commercial Fisheries) as having blotches on its sides and a blunt nose, thus eliminating most other local species including the great white shark (*Carcharodon carcharias*). Moreover, in the recent six months of shark fishing to assess local abundance, the Division's ship "Makua" has caught only two species by setline in inshore water (50–120 feet in depth)—34 tiger sharks and 33 sand sharks. The largest tiger shark taken during this period, 14½ feet in length and 1,200 pounds in weight, approaches the reputed size of the Lanikai killer. However, an element of uncertainty is introduced by Brook Collins' observation that the dorsal fin of the shark appeared black along the edge, suggesting some species other than the tiger.

COMMENT ON SHARK ATTACK

It is noteworthy that the fatal attack occurred before the swimmers were aware that a shark was in the vicinity. If the boys had been skin diving, rather than surfing, they may have discovered its presence. If the shark surfaced prior to the attack, its dorsal fin must have passed unnoticed in the rough surface water.

It is noteworthy that three of the four boys exposed to attack were using air mattresses. Manipulation of the mattress in pushing, boarding, and paddling, requires much more activity than does a surfboard. It is possible that the shark was attracted to the area by this unusual commotion. The vicitm is likely to have been threshing his arms and legs extensively while attempting to catch the wave which carried away his companions.

Tom Replogle reported that he had seen coconut floats, such as are used to mark fish traps, near the scene of the tragedy. A turtle was also observed nearby. It is possible that the shark was attracted to the area by fish caught in the traps or by the turtle.

Although there is no on-the-spot record of water temperature, it was probably about 23° C. This temperature was recorded at the time of the tragedy for the salt water system at the Hawaii Marine Laboratory, Kaneohe Bay, some five miles distant. The water is pumped continuously from a depth of about 10 feet.

SHARK ABUNDANCE

Although quantitative data are not available over a sufficient period of time to measure changes in shark abundance, observations by fishermen and skin divers indicate the abundance has increased in the last few years. This has been attributed to several possible causes:

(1) Cessation of shark fishing because of a recent law (Hawaii Food, Drug and Cosmetic Act, 1941) requiring the labelling of ingredients in Japanese-style fish cake. Although most of the sharks used for this purpose were taken incidental to tuna longlining, which is still active, it is possible that the fishermen now cut the leader line when a shark is captured, allowing

it to go free. This practice would speed up the handling of the gear when using the recently introduced automatic hauler.

(2) Reduction in the inshore fish population, inducing sharks to frequent shallow waters and to become bolder in their search for food. There is not much doubt that the reef fish population is at a low level of abundance because of both commercial and sport fishing pressure. The latter must have increased greatly with the introduction of SCUBA diving gear.

(3) Increase in shark population for some unknown reason. Possibly an increase in abundance occurred following the war period of reduced effort in the longline fishery.

There appears to have been an increase in shark attacks during the past 10 years as compared with a previous 60-year period. Of the 5 (perhaps 6) known fatalities since 1886, 3 (including the present) have occurred in the last 10 years. Of the 11 incidents involving injury by sharks since 1886, 5 have occurred in the last 10 years. Whether the increase is due to the increased number of swimmers and consequent increased number of exposures is unknown.

PUBLIC REACTION

There was immediate and widespread concern over the shark incident, together with public demand for action to reduce the hazard. Bounties were offered by a private individual (Bill Wills, $20 each for 10 sharks) and by a radio station (KPOA, $100 per shark over 15 feet, $25 per smaller shark for sharks caught until the end of December in the vicinity of the tragedy). An action program for reducing shark abundance on a continuing basis was proposed by the Board of Agriculture and Forestry and endorsed by several windward Oahu associations on December 18, 1958. Its activation is contingent on funds to be raised by public subscription. The plans call for a one-vessel, scientifically directed shark fishing program embracing all inshore waters of Oahu. Should this become a reality, efforts will be made to not only control the local shark population but at the same time to gain information on the species composition, abundance, distribution, life history, and behavior of the sharks.

The Billy Weaver Shark Control Program was started April 1, 1959, using the vessel "Holokahana I" with Fred J. Inouye as master. Using three units of 24-hook long-line gear, 595 sharks were caught from the inshore waters of Oahu during the remainder of the year. Of these, 71 were tiger sharks.

Introduction of the Marquesan Sardine, *Harengula vittata* (Cuvier and Valenciennes), to Hawaiian Waters

GARTH I. MURPHY[1]

A PROGRAM of introduction of the Marquesan sardine was undertaken by the Bureau of Commercial Fisheries, Hawaii Area, at the request of the Hawaii Division of Fish and Game. The objective was to introduce a species of fish to the Hawaiian Islands that would be suitable as tuna bait in order to supplement the somewhat tenuous supply of the nehu, *Stolephorus purpureus* Fowler. The stimulus for the request and the subsequent program stemmed from the fact that the fish fauna of the Hawaiian Islands is notable for the number of endemic species and the absence of many forms that are common in the central Pacific islands to the south. Gosline (1955) proposed that the migration route of shore fishes to Hawaii is from the south and that Johnston Island, some 600 miles south of the Hawaiian chain, is the stepping stone. He suggests that the failure of many forms to reach Hawaii can be attributed to the large over-water distance to be traversed in crossing first to Johnston Island and then to Hawaii, to possible ecological screening of fishes at Johnston Island, and finally to the possibility that the Hawaiian Islands do not offer the necessary habitat for certain of the absent forms, especially in regard to species missing in Hawaii but found at Johnston Island.

The Marquesan sardine was first recorded as tuna bait by Royce (1954), who found them to be abundant and accessible in the Marquesas and suitable for tuna fishing. Additional factors suggested that they would be a useful and successful species in Hawaii. They were found along the surf line in the Marquesas but generally along rocky, sandy, sheltered beaches, a habitat not usually frequented by the nehu. (Thus, it did not seem likely that they would compete directly with the nehu.) The Marquesas are high, volcanic islands as are the Hawaiian Islands and, with the exception of the scarcity of coral in the Marquesas, appear to represent the same general type of environment as the Hawaiian Islands.

Negative factors relative to the introduction are the somewhat cooler water temperatures in Hawaii and the fact that our seasons are reversed.

Ordinarily, such an expensive project as transferring a marine fish from 10° south of the Equator to 20° north of the Equator would not be undertaken without an extensive investigation of the fish's life history to evaluate the chances of successful introduction and to weigh thoroughly the possibility that the species might do harm in the new area. The possibility of harm seemed remote, and the expense not critical because a program of introduction could be incorporated in an investigation of the Marquesas area by the Pacific Oceanic Fishery Investigations (now known as the Bureau of Commercial Fisheries, Hawaii Area).

The several releases in Hawaiian waters (Table 1) were made as close to shore as operationally feasible and in habitat situations that were regarded as suitable for the Marquesan sardine. Examination of the gonads of the sardines in Marquesas waters suggested that nearly all of the individuals brought to Hawaii were young, mature adults.

In lieu of an extensive recovery program, wide publicity was given to the releases and a special poster, which included a photograph of the sardine, was widely distributed throughout Hawaii wherever fishermen were likely to congregate. The poster was especially directed to tuna fishermen because they use fine mesh nets when fishing for the nehu. Relying primarily on tuna fishermen for recoveries has several obvious advantages and one serious disadvantage, for one would expect that the Marquesan sardine would not be most abundant in the same habitat as the nehu.

It is not the purpose of this discussion to

[1] Fishery Research Biologist, Bureau of Commercial Fisheries, Hawaii Area, Honolulu, Hawaii. Manuscript received November 17, 1958.

TABLE 1
RECORDS OF THE MARQUESAN SARDINE (*Harengula vittata*) IN HAWAIIAN WATERS

RELEASES				RECOVERIES			
Date	Locality	Estimated number	Fork length (mm.) range and mean	Date	Locality	Number	Fork length (mm.) range and mean
12–17–55	Barbers Point, Oahu	11,000	66–115 (88)				
9–26–56	Hanauma Bay, Oahu	7,000	76–127 (101)				
				9–27–56	Kalihi Channel, Oahu	1	106
3–22–57	Pokai Bay, Oahu	27,000	78–116 (94)				
				3–26–57	Kaneohe Bay, Oahu	1	90
				3–27–57	Kalihi Channel, Oahu	1	90
				4– 8–57	Kaneohe Bay, Oahu	4	87–93 (91)
				6– 4–57	Kaneohe Bay, Oahu	1	103
				9– 9–57	Barbers Point, Oahu	6	120–145 (134)
12–14–57	Ewa, Oahu	31,000	90–111 (99)				
2–25–58	Ewa, Oahu	53,000	72–123 (98)				
				2–28–58	Honolulu Harbor, Oahu	4	82–101 (92)
				4–29–58	Pearl Harbor, Oahu	3	108–114 (111)
5– 2–58	Ewa, Oahu	8,000	47–134 (102)				
6–23–58	Maunalua Bay, Oahu	3,000	84–115 (101)				
				6–27–58	Honolulu Harbor, Oahu	1	102
				6–30–58	Kaneohe Bay, Oahu	1	105
				7– 5–58	Kihei, Maui	10	Not examined
				9–10–58	Port Allen, Kauai	6	67–72 (70)
				9–23–58	Kaneohe Bay, Oahu	1	62
				9–25–58	Hanalei Bay, Kauai	6	74–84 (80)
				10– 2–58	Port Allen, Kauai	6	43–84 (71)
				10– 7–58	Kihei, Maui	29	37–61 (52)

evaluate the program completely to date; the passage of time will furnish definitive information in this respect. The pattern of recoveries in Table 1 however does permit optimism. The first release yielded no recoveries and the second was followed the next day by a single recovery. There were no additional recoveries until a few days after the next release on March 22, 1957, about six months later. It is significant that this planting was nearly three times as large as its predecessors and was followed by a number of recoveries culminating in the capture of six

large adults off Barbers Point by a fisherman, using a gill net. This recapture was significant because (1) the fish recaptured were larger than any planted in Hawaiian waters (in fact the largest were longer than any measured in Marquesan waters), and (2) examination of the specimens suggested that they were very close to spawning. There were no additional recoveries for another six months and these followed close on the heels of an additional release, as did the two recoveries in June, 1958.

In July, September, and October, 1958, there were recoveries that did not fall into the usual pattern. First, the sardine was reported from Kauai and Maui where they had not been planted, and, perhaps more significant, some of the specimens were very small in size, strongly suggesting that there had been successful reproduction.

Of 1,300 fish measured in the Marquesas during the spring of 1958, only 81 were smaller than 75 millimeters. Considering only the last two stockings, only 3 of 50 fish measured were less than 75 millimeters and these were planted in May of 1958. For these small specimens to have originated from the stockings would require both that the fish did not grow during their three or four months' stay in Hawaii, and that there was a highly improbable statistical accident. In view of the growth evinced by the six specimens taken off Barbers Point on September 9, 1957, this seems remote.

In summary, substantial numbers of Marquesan sardines have been released in Hawaiian waters; there have been numerous casual recoveries by commercial fishermen in Hawaii, all indicating that the individuals released were healthy. Finally, there is now at hand good evidence that the species has spawned. To the writer's knowledge, this is the first successful introduction of a purely marine fish species; perhaps the success is not unexpected because of the general impoverishment of the Hawaiian marine fauna and the attendant vacant niches. This type of faunal impoverishment has generally been the basis of the numerous successful fresh water introductions of exotic fishes.

REFERENCES

GOSLINE, W. A. 1955. The inshore fish fauna of Johnston Island, a central Pacific atoll. Pacif. Sci. IX(4): 442–479.

ROYCE, W. F. 1954. Tuna bait survey in the Marquesas and Tuamotus. Pan-Amer. Fisherman 9(1): 10–11.

News Notes

A *Handbook of Hawaiian Fishes*, written by William A. Gosline and Vernon E. Brock, has just been published by the University of Hawaii Press. It is the first work since that of Jordan and Evermann in 1905 to give the information needed for the identification of all of the inshore species of fishes recognized from the Hawaiian Islands and their adjacent waters. As such, it is a complex and important undertaking, which has been carefully prepared by its authors and handsomely printed by the University of Hawaii Press. It will be of value not only to ichthyologists but to anyone whose interest in Hawaii's fishes extends to the point of wanting to learn which ones they are. Teachers of marine biology, commercial fishermen confronted with unfamiliar specimens in their hauls, biostatisticians, law-enforcement agents, students, and plain people who wish to be knowledgeable about their catches, all will find this *Handbook* both useful and instructive.

No book can make ichthyology easy, but this one makes the fundamentals of the science easier to acquire than would most texts upon the subject. It avoids the almost unintelligible language of the specialists, using instead a sensible informal style which is both descriptive and reliable. The result is a work that makes taxonomy, as the authors intended it to be, "as painless as possible," without sacrificing either accuracy or the details of systematics.

In its 371 pages, the *Handbook* presents all of the information needed for the identification of 584 species of native Hawaiian fishes, together with 15 species that are not yet known north of Johnston Island, and about 30 others that have been intentionally introduced to the Hawaiian Islands. When it is known, the common name generally applied to a fish in Hawaii is listed with the scientific name of that fish.

The relationships of the deep-water forms, of which 136 are discussed in the *Handbook*, are still too little known to permit a lasting classification, and, wisely, the authors carry their accounts of these fishes "only to the family level." All of the 448 forms of inshore or surface-living fishes are keyed to species, however, and for each of these a short description is given. Five color plates, two large end-paper maps of the Indo-Pacific area, and 277 elegant line drawings illustrate the book.

Almost as important as the taxonomic portions are the introductory chapters which discuss the history of ichthyological research in the central Pacific, especially in Hawaii; the ecology of Hawaiian fishes (with some pertinent notes on fish populations and productivity); and the nature and derivation of the Hawaiian fish fauna. These chapters offer definitive, if brief, summations of all the information concerning Hawaiian fishes that has been gathered by biologists working in the immense area of the Indo-Pacific. The book concludes with both an index and an annotated checklist of the native Hawaii fishes.

The authors come well qualified to their service as writers of this book. William A. Gosline has been a Professor of Zoology at the University of Hawaii since 1948. Vernon E. Brock, since February, 1959, Director of the Hawaii Area Office of the U. S. Department of Interior's Bureau of Commercial Fisheries (formerly known as POFI), was Director of the Division of Fish and Game for the Territory of Hawaii from 1944 to 1958. Their colleagues and students have helped them to perfect the many keys which now find a place in the *Handbook;* and, in a collaboration that is as pleasing to the observer as it must be gratifying to themselves, three of their former students have contributed sections to the taxonomic treatment of the fishes upon which they have become authorities: Yoshio Yamaguchi wrote the section on the Carangidae; John E. Randall, that on the Acanthuridae; and Donald W. Strasburg, that on the blennioid fishes.

In the first lines of their book, the authors state, with the wry humor that is characteristic of them, "It is probable that the Hawaiians of Captain Cook's time knew more about the fishes of their islands than is known today. Most of this information has now been lost." This is a proper deference to the ancient Hawaiians, of course, but, one suspects, it is also a restrained gibe at modern man with his incredible apparatus of fallible machines, multiplying memoranda, and progressive myopia, who can scarcely see the fishes in the sea around him, let alone catch 'em or name 'em. Whether or not this is so, it is clear that upon the occasion of the publication of their *Handbook,* Gosline and Brock themselves deserve a bow of tribute for their many labors, of which this is only the latest, to acquaint modern man with the creatures of the sea.—O. A. BUSHNELL

Pacific Insects, a new journal for the publication of systematic and zoogeographic papers dealing with insects and terrestrial arthropods from the Pacific area including Eastern Asia and the Antipodes, appeared on July 15, 1959. It is established as an organ of the program on zoogeography and evolution of Pacific insects of the Bernice P. Bishop Museum. It is planned as a quarterly of approximately 400 pages per year. The first number of 172 pages contained three papers on Diptera, Formicidae, and Coleoptera.

On good-quality paper with very good work on the illustrations, the journal, which is well edited, is a welcome addition to the available vehicles for publication of papers on insects of the Pacific region. The board of editors is broadly representative and of a stature which should ensure the continued high quality of the journal.

Authors are requested to correspond with the editor regarding publication prior to sending manuscripts. The editor is J. L. Gressitt, Bernice P. Bishop Museum, Honolulu.—L. D. TUTHILL

should not be fastened together in any way, and should be mailed flat. Inserts should be either typed on separate sheets or pasted on proper page, and point of insertion should be clearly indicated.

Original copy and one carbon copy of manuscript should be submitted. The author should retain a carbon copy. Although due care will be taken, the editors cannot be responsible for loss of manuscripts.

Introduction and Summary. It is desirable to state the purpose and scope of the paper in an introductory paragraph and to give a summary of results at the end of the paper.

Dictionary Style. It is recommended that authors follow capitalization, spelling, compounding, abbreviations, etc., given in *Webster's New International Dictionary* (unabridged), second edition; or, if desired, the *Oxford Dictionary*. Abbreviations of titles of publications should, if possible, follow those given in *World List of Scientific Periodicals*. Examples of the usual abbreviations are to be found in *Pacific Science*.

Footnotes. Footnotes should be used sparingly and never for citing references (see later). When used, footnotes should be consecutively numbered by superior figures throughout the body of the paper. Footnotes should be typed in the body of the manuscript on a line immediately below the citation, and separated from the text by lines running across the page.

Citations of Printed Sources. All references cited should be listed alphabetically by author at the end of the paper, typed double-spaced. References to books and to papers in periodicals should conform to the following models:

BATZO, RODERICK L., and J. K. RIPKIN. 1849. A Treatise on Pacific Gastropods. Rice and Shipley, Boston. vii + 326 pp., 8 figs., 1 map.

CRAWFORD, DAVID L. 1920*a*. New or interesting Psyllidae of the Pacific Coast (Homop.). Proc. Hawaii. Ent. Soc. 4(1): 12–14.

——— 1920*b*. Cerotrioza (Psyllidae, Homoptera). Proc. Hawaii. Ent. Soc. 4(2): 374–375.

ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revison of the Hawaiian species of the genus *Santalum*. J. Aust. Inst. Agric. Sci. 12(3): 1–43, 13 pls.

In the text, sources should be referred to by author, date, and page, as follows: "It was noted (Rock, 1916: 18) that . . ." or "Rock (1916: 21–24) says . . ."

Quotations. Quoted matter of fewer than five printed lines (about 200 characters) should be given in the text in the usual form, using double quote marks. Longer quotations should be set flush with left margin. The author is responsible for the accuracy of quoted material.

Numbers. Decimals, measurements, money, percentages, time; enumerations in which any figure is 10 or over; and isolated enumerations of 10 and over should be given in Arabic figures, rather than spelled out, except when the number begins a sentence.

ILLUSTRATIVE MATTER

Only the minimum number of illustrations required to supplement the text will be accepted by the editors. Reproduction costs of illustrations in excess of the number allowed by the editors will be paid by the author.

Illustrations should accompany manuscript, on separate sheets. Often more valuable than a photograph is a good line drawing, which may be reproduced by the zinc etching process.

Figures and Graphs. Copy for figures and graphs should always be drawn large enough to allow for at least one-third reduction by the engraver. Copy should consist of carefully prepared line drawings in one color only, drawn in India ink on plain white drawing paper or tracing cloth. Co-ordinate paper with lines in light blue (a color which will not show in a photograph) may be used; but co-ordinates which should appear in the finished graph must be drawn in India ink. If original figures may not be conveniently submitted with manuscript, duplicate rough sketches or photographic prints may be furnished to aid the editors in their decisions.

It is strongly urged that an indication of scale be incorporated as a part of all drawings in which magnification and size are critical considerations.

Photographs. Photographs should be chosen for clarity in portraying essential information. They should be printed for contrast, on glossy paper, and should be sent unmounted. They should be identified with serial number written in soft pencil on the back to correspond with list of captions.

Illustrations will be returned to the author.

Tables. Tabular matter should be kept to a minimum. Each table, prepared to conform with *Pacific Science* style, should be typed on a separate page, and its position indicated on the manuscript.

Captions. Readily identifiable captions for figures, graphs, photographs, and other illustrative matter should be supplied on a separate page.

PROOF

Proof should be corrected immediately and returned *at once* to Robert Sparks, assistant to the editors. Authors are reminded that the editors will allow only a minimum number of corrections on galley proof. Additions to the printed text and changes in style and content are not permitted.

All queries on proof should be answered. If corrected proof is not received within four weeks after being sent to the author, author's changes cannot be accepted.

REPRINTS

Reprints or separates should be ordered on the form provided and returned with author's proof. *All correspondence concerning separates must be directed to the printer,* Star-Bulletin Printing Company, Inc., 420 Ward Avenue, Honolulu 14, Hawaii.

U P H